ANALYSIS OF THE STRESSES AND DEFLECTIONS OF A LNG TANKER.

Richard Sterling Tweedie

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by

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ABSTRACT

The objectives of this thesis are to 1) determine the deflections of the horizontal and vertical tank supports when the ship is subjected to various loading conditions, and, 2) determine the stresses in the hull and support platforms for these loading conditions. This information, especially the deflections of the support platform, is needed to determine the forces that will be transmitted from the ship through the articulated vertical support system to the large spherical pressure vessels that carry the cargo. This information will permit a more complete analysis of the spherical tank.

This paper details how the beam element capability of ICES STRUDL was used to determine the stresses and deflections. A quarter tank section of the ship is modeled as a three dimensional arrangement of beams. This model is then subjected to loads that simulate the loads the actual quarter tank section would experience.

The results indicate that the maximum vertical deflections of the support platform out of a horizontal plane are less than a centimeter for the loadings investigated. The circular hold deforms out of its circular shape in all the loadings as one would expect. The maximum horizontal movement of any support point on the circular support platform is less than 3 centimeters. Relatively high longitudinal stresses are found in the main deck at the transverse centerline of the tank. Areas of high bending stresses are pointed out and should be further investigated using means other than a beam element model due to modeling difficulties.

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INTRODUCTION

The first carriage of liquified natural gas (LNG) occurred in 1958 on an experimental basis with the conversion of an old C1 dry cargo ship into the Methane Pioneer. Successful commercial ventures took place in 1964 when the first new ships specifically designed for the transportation of LNG were completed and put into service. At the present time there are approximately 20 LNG tankers in use.

The reason for this large growth of interest in the marine transportation of liquified natural gas has been the world wide shortages that have been caused not only by increasing general demand, but also because of the demand for "clean" fuels which is inspired by the ecological concern being expressed at the present time. Natural gas is the cleanest burning fuel that is available at the present time with the exception of hydrogen.

Natural gas is often a by-product of oil drilling operations and has often been considered a waste product in the past, especially in areas remote from consumers. Transportation of this fuel in the gaseous state would be economically infeasible due to the large volume required. However, it was determined that if the gas could be liquified, the required volume per unit weight could be greatly reduced.

The principal constituent of natural gas is methane

which has a boiling point of -258.6 degrees Fahrenheit and a gas to liquid volume ratio of 630:1 (Ref. 1). Thus, if the temperature of the natural gas is reduced below -260 degrees Fahrenheit, the same amount of fuel could be carried in 1/630 of the volume of the gas at room temperature.

These low temperatures caused several technical problems of which the principal one was probably brittle fracture in steel. Thus, the tank material must have a ductile to brittle transition temperature well below -260 degrees Fahrenheit. The materials used for the construction of the LNG tanks to date have been aluminum, stainless steel, Invar (36 per cent nickel-iron alloy) and 9 per cent nickel steel (Ref. 12). The problem of brittle fracture required these tanks to be thermally insulated from the hull of the ship which is constructed of mild steel.

There have evolved two basic tank types by which LNG is carried—the self-supporting tank and the membrane tank. There are several differing designs of each basic tank with varying support systems, insulations, tank shapes, materials, and type of secondary barrier, if any.

Membrane tanks are designed such that they are liquid tight only, with the intention that the normal loading forces would be transmitted through the thermal insulation to the hull structure on the other side. Membrane tanks require a secondary barrier. The secondary barrier must be designed to contain a catastrophic failure of the membrane

for a reasonable amount of time (Ref. 9).

There are two basic types of self-supporting tanks— pressure vessels and free standing tanks. Pressure vessels, due to their shapes, are amenable to analytical stress analysis and are constructed in accordance with pressure vessel requirements. Free standing tanks are basically tanks, usually of rectangular or trapezoidal shape, that are set inside the ship's hull on supports. The advantage of the free standing tank over the pressure vessel is that it can conform more nearly to the ship's hull configuration. The disadvantage is that the free standing tanks require a secondary barrier and the pressure vessels do not. As a result of economic considerations, some recent designs have been of very large pressure vessels having low vapor pressures with the differences between the two types of free standing tanks becoming indistinguishable. The distinction between free standing tanks and pressure vessels varies among the regulatory agencies, however, the use of a vapor pressure of 10 psig as a demarcation limit is common.

The United States Coast Guard, which is charged with the regulation of the marine industry from the safety aspect, has recently defined four types of self-supporting tanks (Ref. 16).

1. Independent Pressure Vessel Tanks — These are pressure vessels with the vapor pressure P greater than D+20 where D is the diameter in feet and

where P is at least 40 psig.

2. Semi-Independent Pressure Vessels — This category includes pressure vessel tanks where the vapor pressure is less than for the independent pressure vessels.
3. Independent Structurally Indeterminate Self-Supporting Gravity Tanks — These are free standing tanks in which the maximum vapor pressure is less than 10 psig.
4. Independent Structurally Semi-Determinate Self-Supporting Gravity Tanks — These are large tanks with vapor pressures under 10 psig that are usually designed using finite element and/or fracture mechanic techniques to pressure vessel standards. This class of tank generally will be required to have only a partial liquid tight, splash tight secondary barrier.

The proposed tanks for the Technigaz design that is being analyzed fall into category 4.

DESCRIPTION OF THE SHIP AND CARGO TANKS

The Ship

This analysis was undertaken as part of the design process for the Technigaz 125,000 cubic meter methane carrier design. The principle characteristics of the design are as follows:

Length overall	290.6	meters
Length between perpendiculars	275.0	meters
Breadth, molded	44.0	meters
Depth(at main deck)	26.0	meters
Draft	10.97	meters
Block coefficient	0.775	

The cargo tanks consist of five spherical tanks vertically supported at their equator (Fig. 1 and 2). The spaces for these spherical tanks occupy a large portion of the deck area necessitating the requirment of very heavy plating (45 millimeters thick) at the deck and sheer strake junction to provide longitudinal material in tension, stiffness against lateral loads from the sea, and resistance to buckling in the sagging condition.

Longitudinal bulkheads, located 8.9 meters inboard from the outer hull except in way of tank holds, provide the lateral subdivision for wing tanks which are used for ballast (Fig. 3). The double bottom is composed of longitu-

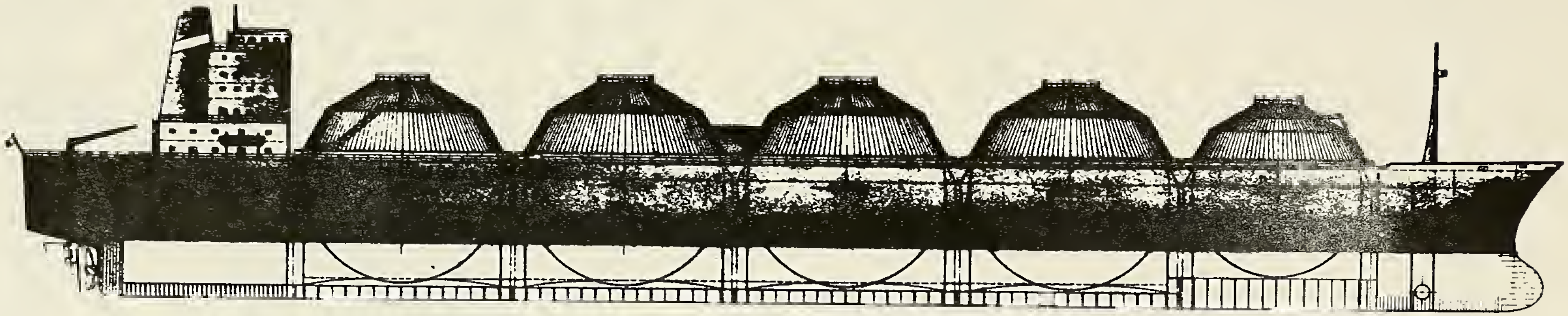


FIGURE 1

TECHNIGAZ LIQUIFIED NATURAL GAS TANKER

125,000 CUBIC METER DESIGN

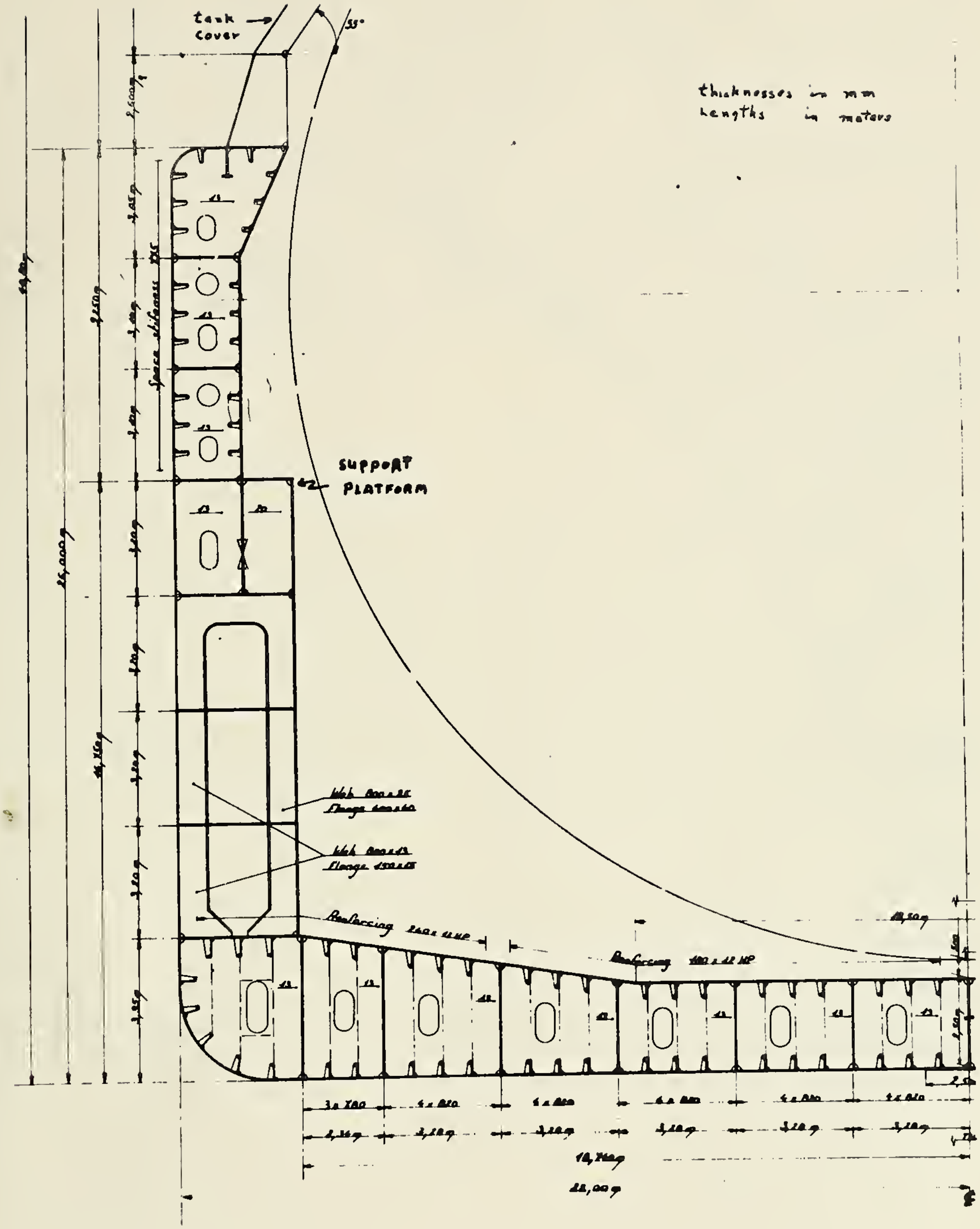


FIGURE 2

MIDSHIP SECTION - FRAME 228

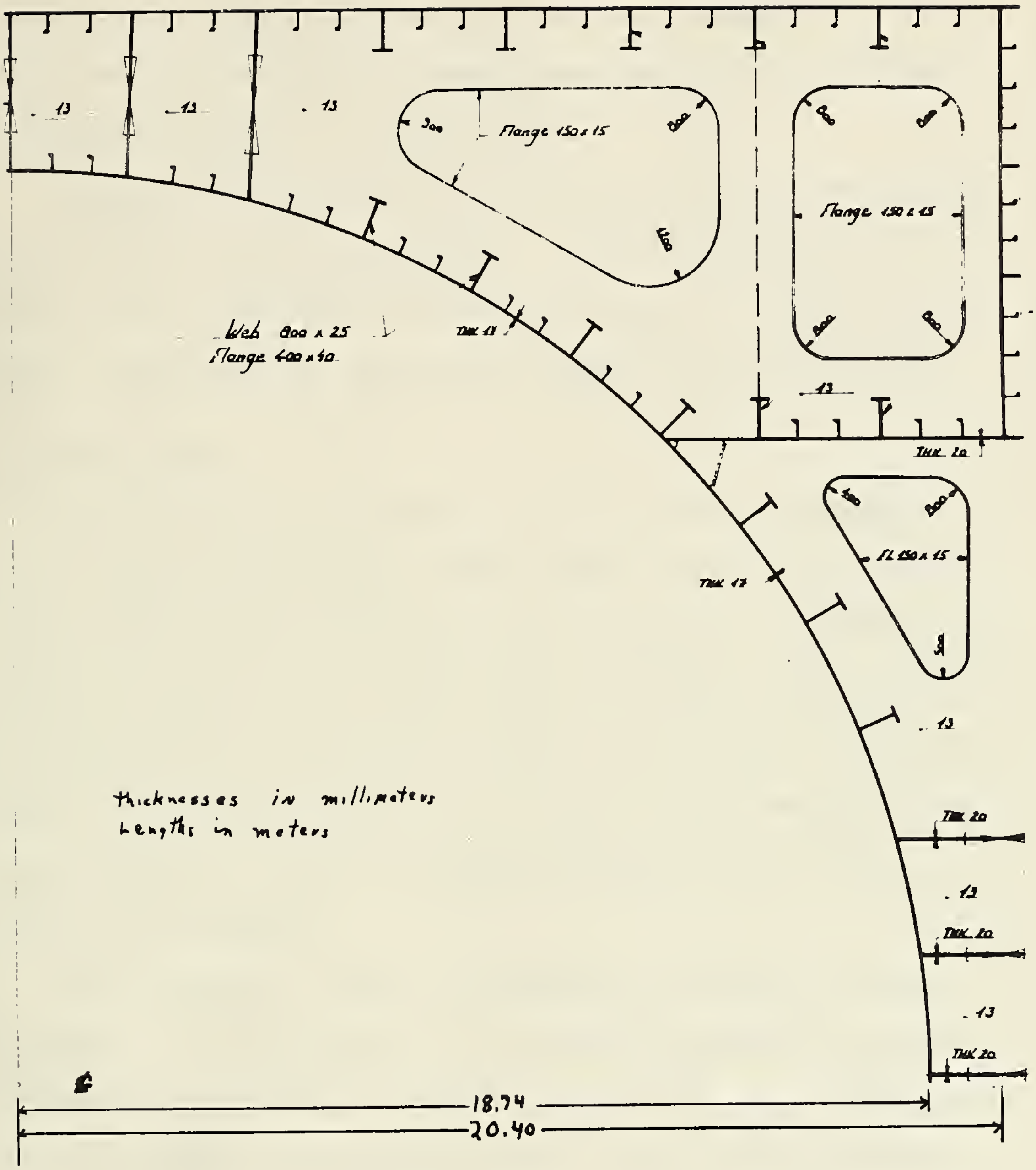


FIGURE 3

TYPICAL DECK - QUARTER TANK SECTION

dinal plates spaced 3.28 meters apart. In addition the inner and outer bottoms are strengthened by longitudinal stiffeners spaced .82 meters apart.

Transversely the hull is stiffened by deep web frames in the double bottom and sides. The frame spacing is .85 meters with a web frame every 2.55 meters. There are six decks in addition to the double bottom and the main deck.

The Cargo Tanks

The cargo tanks consist of five spherical tanks of semi-independent pressure vessel type. Tank 1 has an inside diameter of 31.6 meters and a capacity of 16,520 cubic meters. Tanks 2, 3, 4, and 5 have an inside diameter of 37.5 meters and a volume of 27,610 cubic meters. This results in a maximum capacity of 126,965 cubic meters. The useful capacity, using a maximum filling ratio of 98%, is 124,450 cubic meters.

The spherical tanks are supported, in the vertical direction, at the equator by a patented system of articulated parallelograms of rods and arms (Fig. 4). This system is attached to brackets at the tank equator and then extend down to the support platform. Horizontal restraint to pitch and roll is provided by keys and keyways. These keys are installed on two circles parallel to the equator at the approximate positions of the Tropic of Cancer and Tropic of Capricorn.

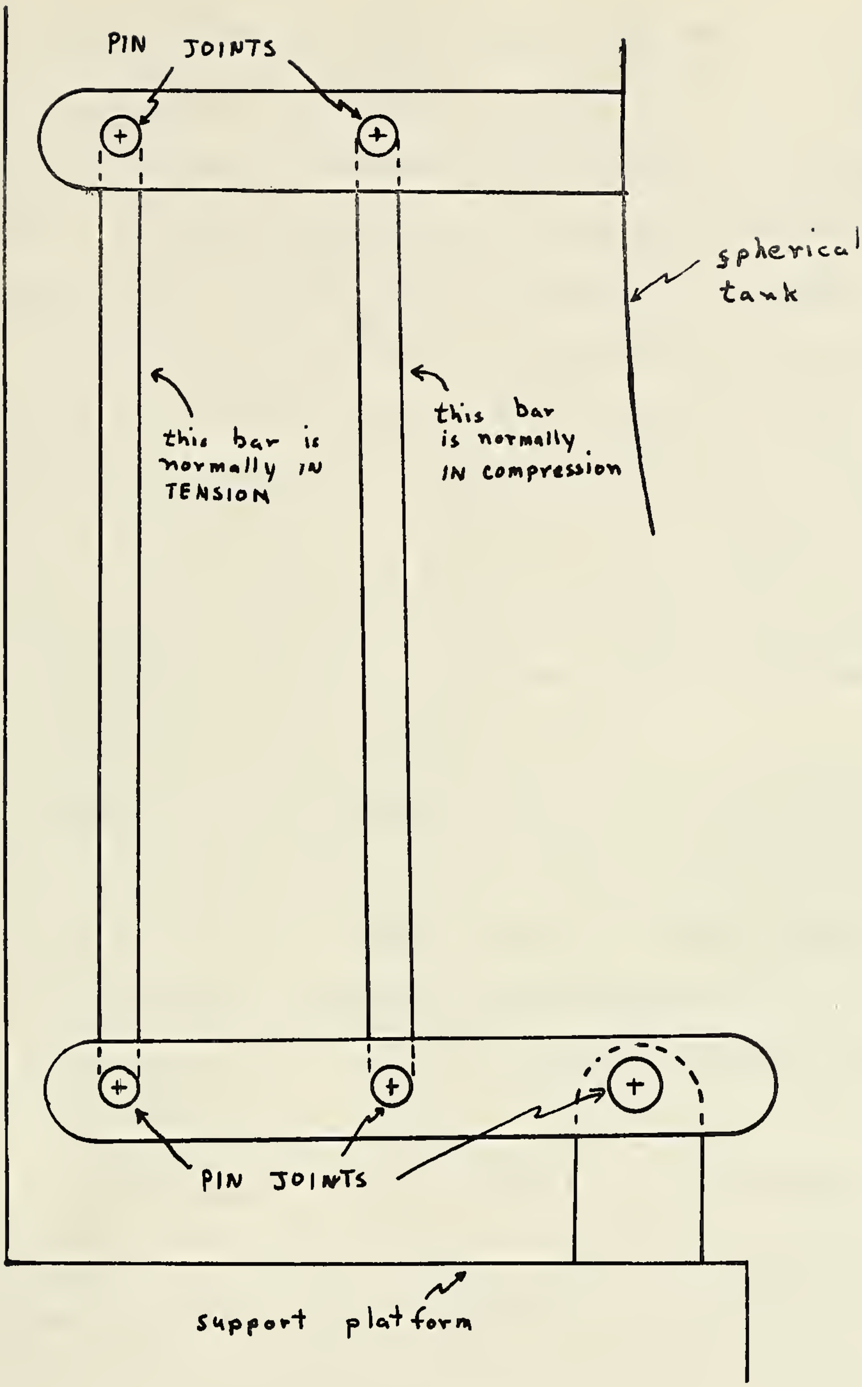


FIGURE 4

TECHNIGAZ ARTICULATED SUPPORT SYSTEM

The purpose of the vertical support system of articulated parallelograms is to allow the cargo and tank weight to be supported without a bending moment being introduced in the shell. It also allows for the thermal contraction of the sphere while carrying the cold cargo. The keys change the horizontal forces due to pitch and roll to tangential forces on the tank shell. The purpose of these elaborate support systems is to allow only forces that can be structurally analyzed to be imparted to the spherical tanks. This allows the tank plating thickness to be reduced to the minimum possible thickness and also allows a possible reduction in the secondary barrier.

The present proposed design scheme is to fit insulation around the tank inside the inner hull with the inner face of the insulation acting as a spray shield in case of tank leakage. A drip pan is fitted in the bottom of the hold to collect any drippings and to act as a local secondary barrier.

One of the purposes of this thesis is to determine the deflections of the vertical support platform and the keyways in order that the forces imparted to the sphere may be determined prior to a structural analysis of the shpere, which is required before a reduction in the secondary barrier will be permitted by the regulatory agencies.

MATHEMATICAL MODEL

General Discussion

The solution method that appeared particularly suited to the task of solving for the deflections of the horizontal and vertical tank supports as well as solving for the stress levels in the various structural members was some type of beam or plate element solution. Recent advances and knowledge in this field have been extensive. Predicted stress levels obtained by this type of analysis have shown a good correlation with actual results obtained from strain gages on ships at sea.

It is fortunate that these elemental solutions have been developed since the traditional naval architectural methods of stress calculations would probably have been inadequate for the unconventional geometry of this vessel. The fact that the section modulus varies with length (large portions of the decks are cut out to make way for the spherical tanks) makes standard calculations difficult if not impossible.

There are several element type computer programs available that have either been developed specifically for ships or that are general purpose. Some of these, such as ICES STRUDL-II, developed by Massachusetts Institute of Technology for use on IBM 360/370 (Ref. 7 and 8) and DAISY (Ref. 10), developed by the University of Arizona in conjunction

with American Bureau of Shipping for use on both CDC 6000 series and for the UNIVAC 1108 computers, have user oriented languages. Other programs exist, especially in the aerospace field, where the stiffness matrix is assembled by hand and a computer is used for the solution.

The decision was made to use the M.I.T. developed ICES STRUDL-II (Integrated Civil Engineering System-Structural Design Language) program which is a series of computer programs that can be used in conjunction with each other to solve problems in structural engineering. The STRUDL program was selected primarily because of time consideration. The time required to develop a finite element program particularly suited to this ship structure, would have been prohibitive. Another advantage of STRUDL is that the language is easily understandable to an engineer in that the words and phrases in the input are such that their meaning is usually self-evident.

Several different types of analysis procedures are currently available in STRUDL for solving framed structures and continuum mechanics problems. The member stiffness matrix in the frame analysis is computed from beam theory, while continuous mechanic problems are solved with the finite element capability and the element stiffness matrix is computed from energy considerations. STRUDL allows for the mixing of members and elements provided they have the same number of degrees of freedom per joint and these free-

doms correspond in type and direction.

Analyses of ship structures have been carried out using beam elements as well as finite elements. Stiansen and Elbaloute (Ref. 15) did a thorough study of SL-7 container ship design using DAISY. Fenton (Ref. 4) used the finite element capability of STRUDL to obtain stresses in a catamaran cross structure. Zoller (Ref. 17) combined beams and finite elements in a tanker study with satisfactory results.

It is very important to use the analysis procedure that is best suited for the problem since the number of elements or members required for even a coarse node network of a complex structure can become extremely large with the stiffness matrix computer core requirements exceeding the capacity of the computer.

The decision was made to use beam elements in this study. The main reason being that the complexity of the structure, caused by the circular hold for the spherical tanks, required a fairly fine mesh with all joints having six degrees of freedom to get any meaningful deflections. This would have required an extremely large number of elements if the finite element capability was utilized, since plate bending elements would have to be superimposed on plane stress elements to account for loads in all three coordinates. Any combination space frame and finite element would be completely out of the question for the same reason.

The stiffness analysis carried out by STRUDL is a

linear, elastic, static, small displacement analysis. The procedure used requires the specification of the model geometry, the member and joint loads, the member properties and various applicable constants, such as, Young's modulus and Poisson's ratio. The analysis used treats the joint displacements as unknowns. When a space frame is specified as the structural type, as it was in this problem, there are six unknowns at each joint—three displacements and three rotations.

The stiffness analysis is comprised of the following steps:

1. Consistency checks of members
2. Generation of the stiffness matrix
3. Processing of member loads
4. Stiffness matrix assembling
5. Processing of the joints
6. Solution of the matrix
7. Joint displacement processing
8. Processing of member stresses

Beam Model

The area of the midship section around Tank 3 was the section selected for study. This area was chosen because the maximum bending moment occurred in this region for the loading conditions that were to be analyzed. This area would then give the maximum amount of deflection of the support platform as well as the largest stresses—the two parameters that were to be determined.

In order to keep the bandwidth of the stiffness matrix as small as possible and still get valid results it is advantageous to limit the size of the model. First it was possible to limit the model size by the use of symmetry of both the structure and the loading of the ship about the centerline of the vessel for the cases being investigated. This cut the size of the model in half. Furthermore, with approximate symmetry of the moment curve and internal structure of the ship about frame 228, it was decided that sufficient symmetry did exist to further reduce the model. Thus the model could be reduced to a quarter tank section extending from frame 195 to frame 228 with the necessary boundary conditions at frame 195 to simulate the remainder of the vessel.

All joints in the transverse plane of symmetry through the center of the tank and in the longitudinal plane of symmetry along the centerline of the vessel must be supported. STRUDL assumes that all joints specified as sup-

port joints to be rigidly supported according to structural type with no displacements or rotation unless specifically released in a certain direction. Thus, to insure an accurate representation of the actual ship, it was necessary to release the constraints in the Y and Z direction as well as the rotation constraint about the X axis for joints in the transverse plane of symmetry. In the longitudinal plane of symmetry, it was necessary to release the force constraints in the X and Z direction in addition to the rotational constraint about the Y axis. The origin, the center of the tank hold in the double bottom, remained completely fixed to provide a reference point.

The structural members of the ship were idealized, as indicated previously, by beams. The object of this modeling process was to accurately represent the ship, while at the same time trying to keep the number of beam elements to a minimum because of computer space considerations. The model that was finally settled upon idealized two actual ship decks as one deck in the model. In the horizontal plane the flanges of the beam element were the deck plating and the vertical members formed the web of the beams. The effective breadth of plating was calculated for bending in both the transverse and longitudinal directions. Examples of beam elements formed from the double bottom and support platform are shown in figures 5 and 6.

The vertical beam elements were handled in basically

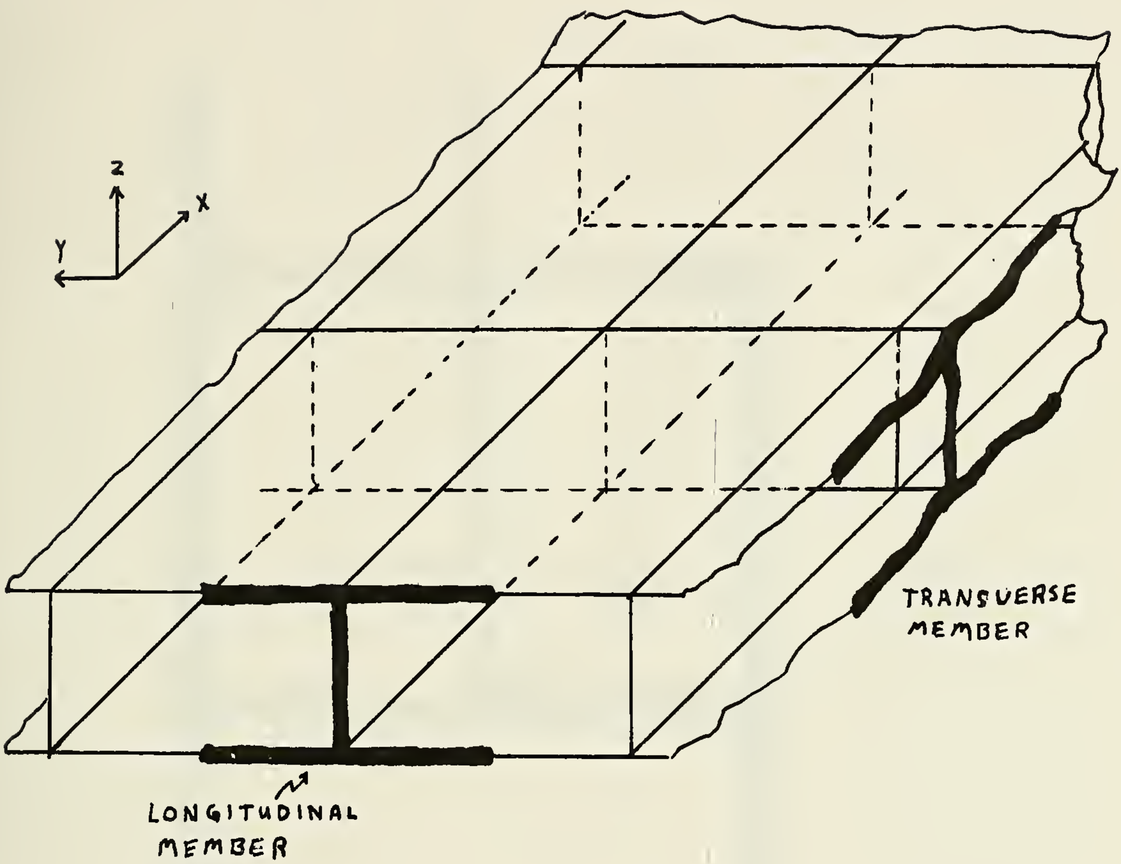


FIGURE 5

DERIVATION OF BEAM ELEMENT CROSS-SECTIONS
FROM CELLULAR DOUBLE BOTTOM

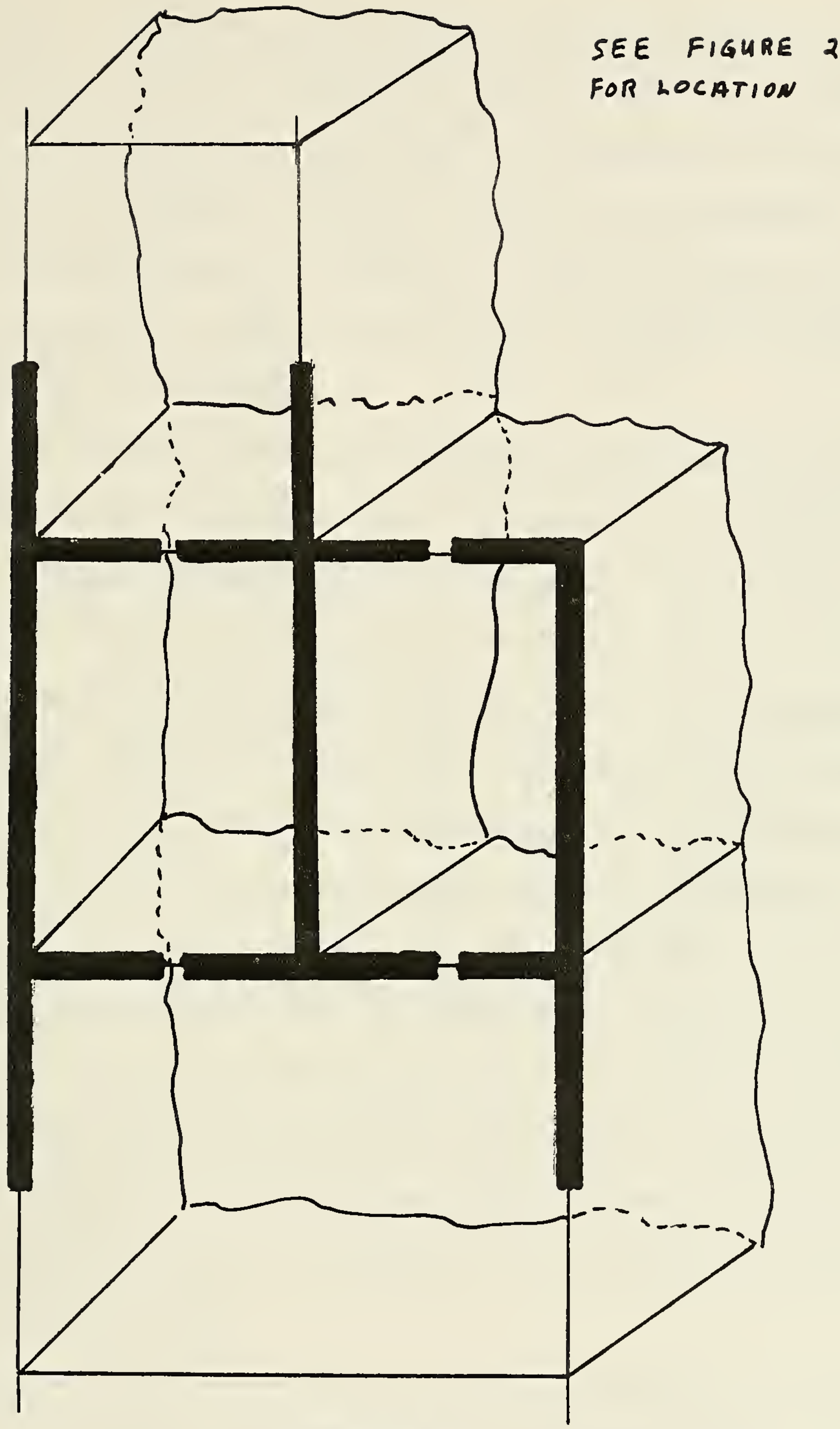


FIGURE 6

DERIVATION OF BEAM ELEMENT CROSS SECTIONS

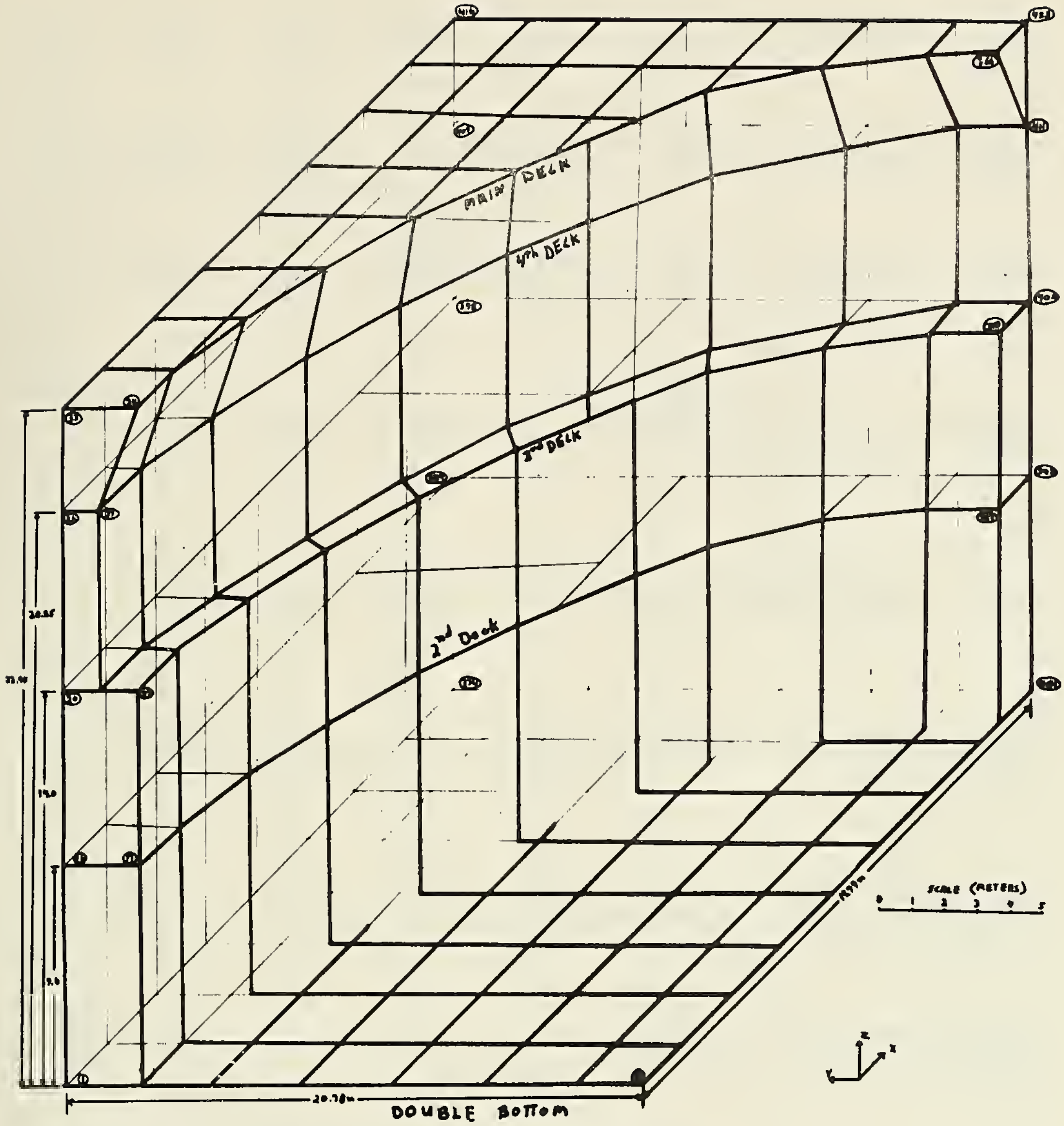
FROM SUPPORT PLATFORM DECKS

the same way. Generally the beam elements consisted of tee bars welded to plating. This was true for the outer vertical hull, the bulkhead at the inner web frames, and the circular support platform. Figure 7 depicts the geometric shape of the beam model. Figures 8 through 16 show the individual joints and member numbers for the various joints and bulkheads of the model.

The major problem that developed in the modeling process involved the circular support platform. One characteristic of beam elements is that the ends must always be at a joint. Thus it was necessary that the vertical members at least butt on a longitudinal or transverse member of the double bottom. These joints have numbers 75, 115, 156, 198, 251, and 253 in the model(Fig. 8). This restriction prohibited the vertical members from being equally spaced as in the actual ship. The equal spacing in the ship design was accomplished by the use of vertical stiffner plates in the double bottom under the vertical members.

The model did not take into account such details as the rounded bilge or rounded deck edge, however, the effect of these idealizations were judged to be negligible when compared to mesh used.

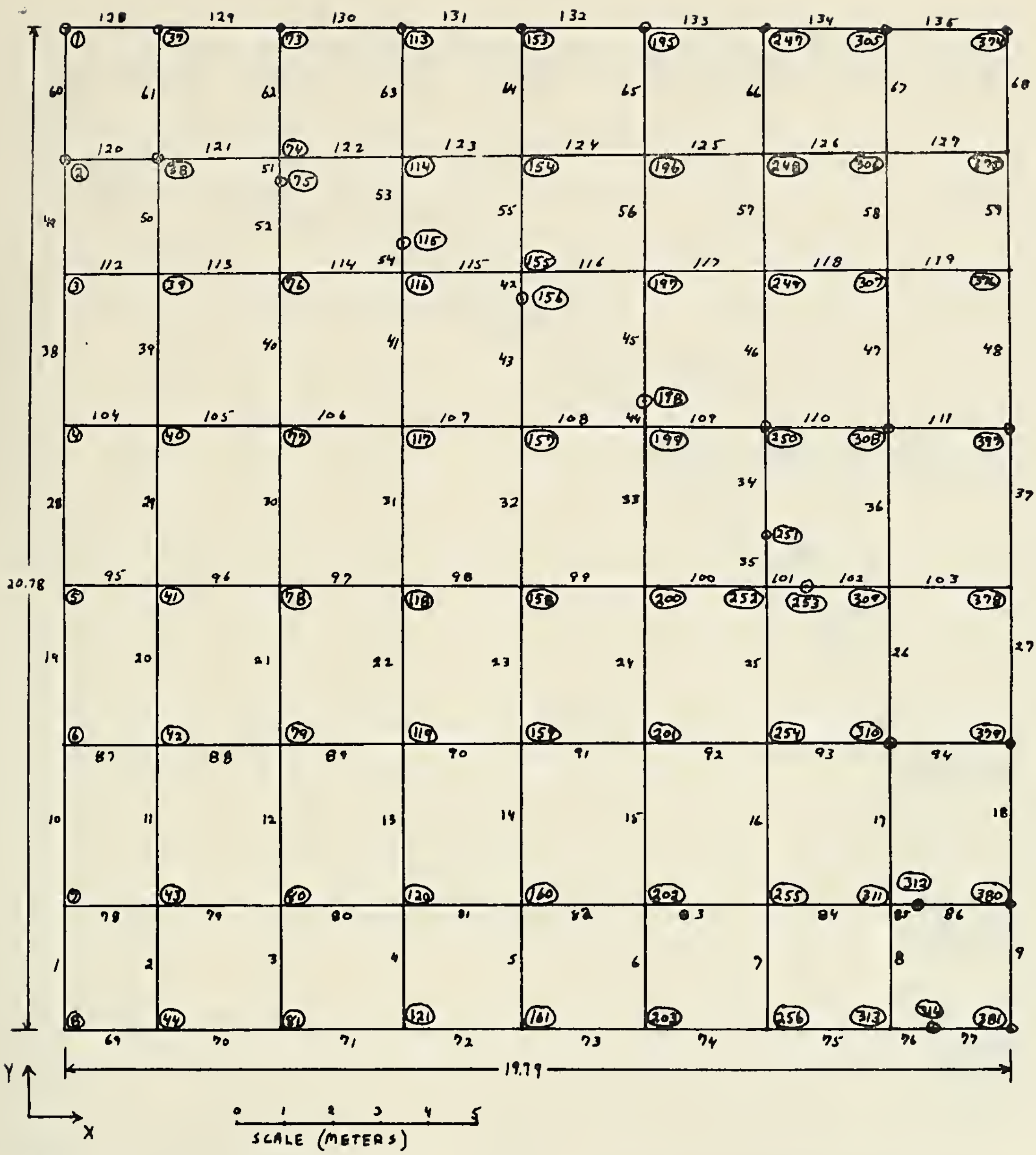
It should be pointed out here that the point of connection of the beam elements is at the neutral axis of the element. This is the reason for the small difference in the actual beam and depth when compared to the model scale



Straight line indicates beam element

FIGURE 7

THREE DIMENSIONAL VIEW OF THE BEAM MODEL



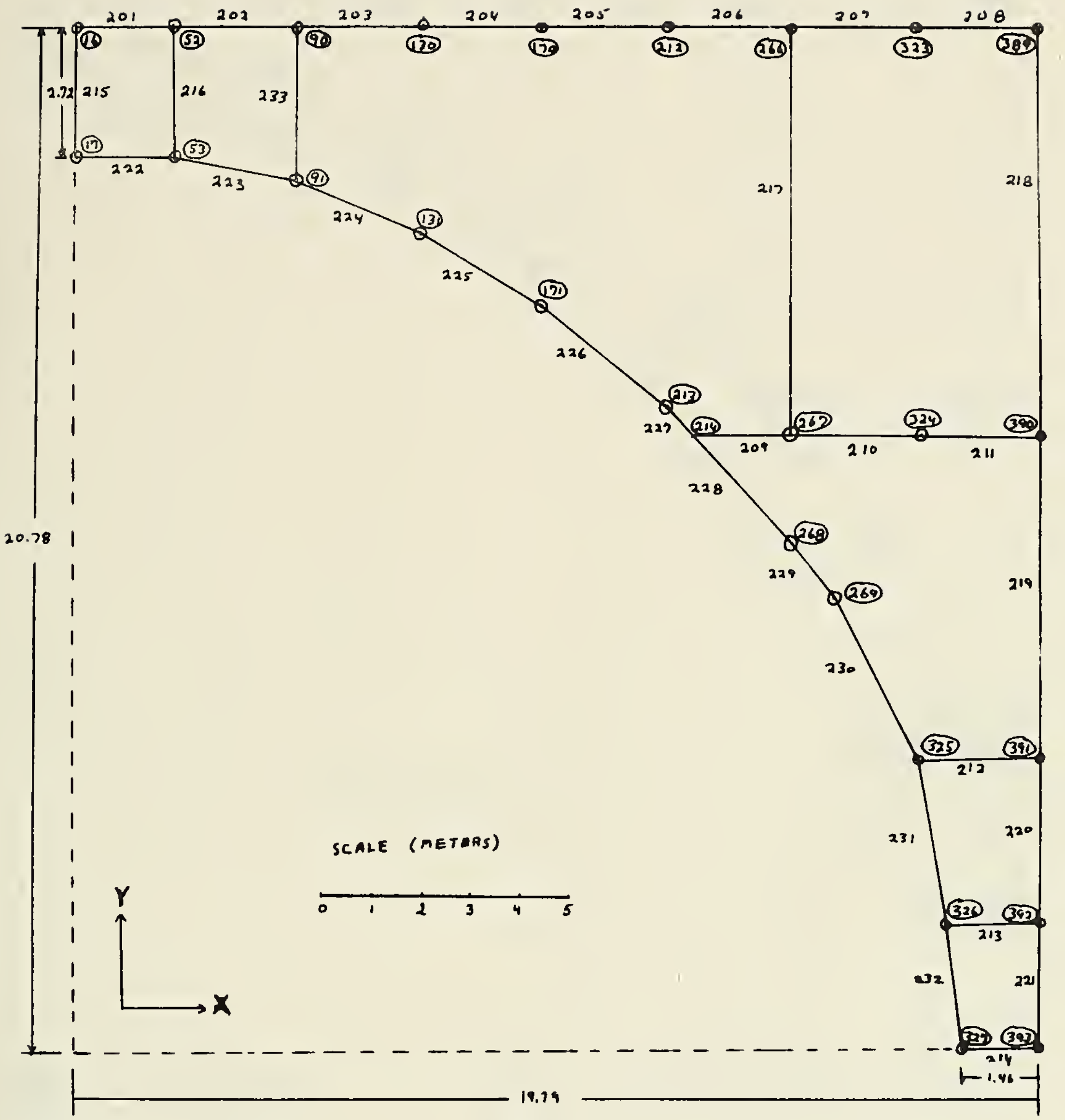
(10) joint number

10 member number

indicates that a vertical member goes up from the joint

FIGURE 8

BOTTOM DECK OF BEAM MODEL



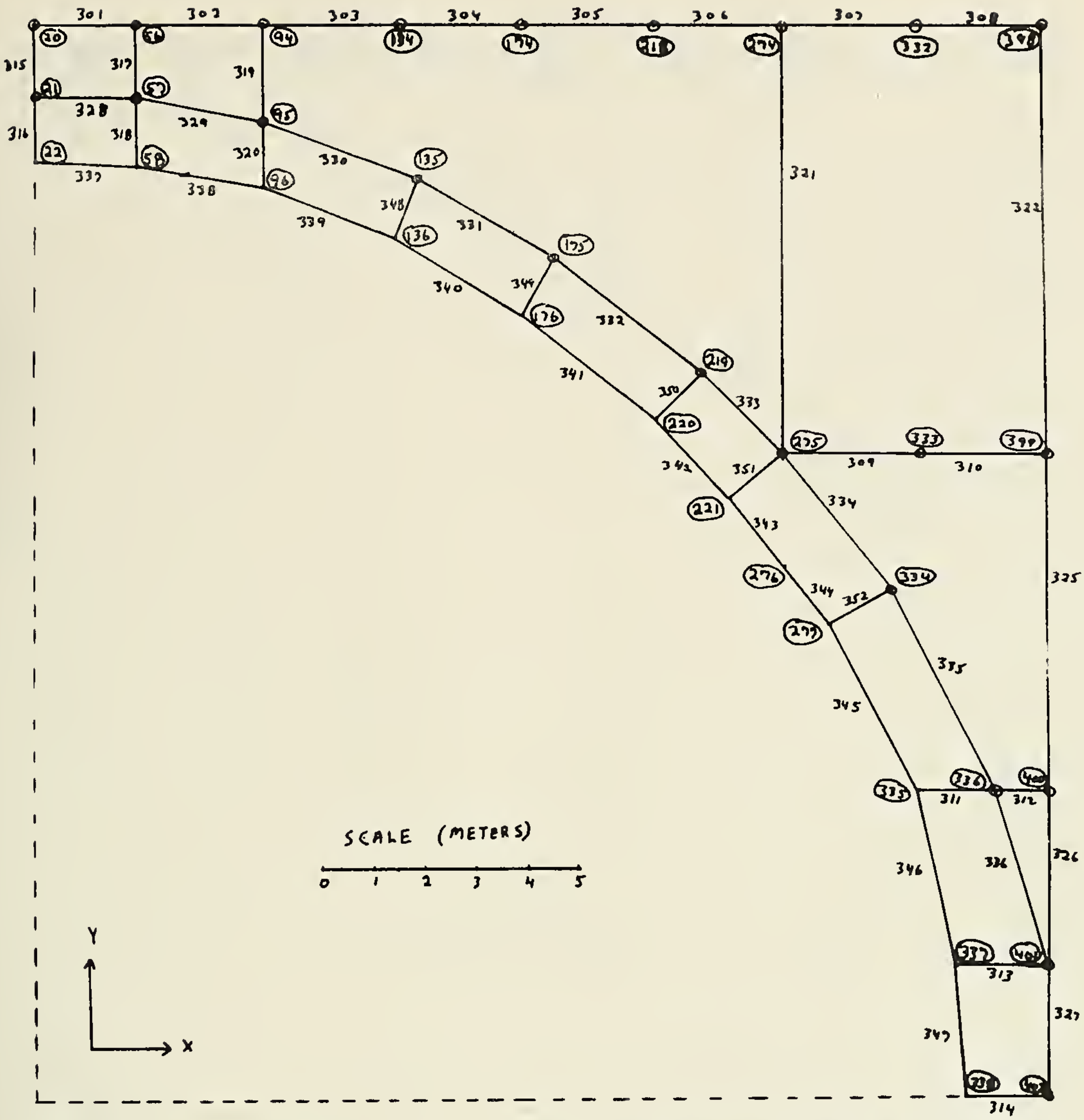
(10) joint number

10 member number

indicates that a vertical member goes up from the joint

FIGURE 9

SECOND DECK OF BEAM MODEL



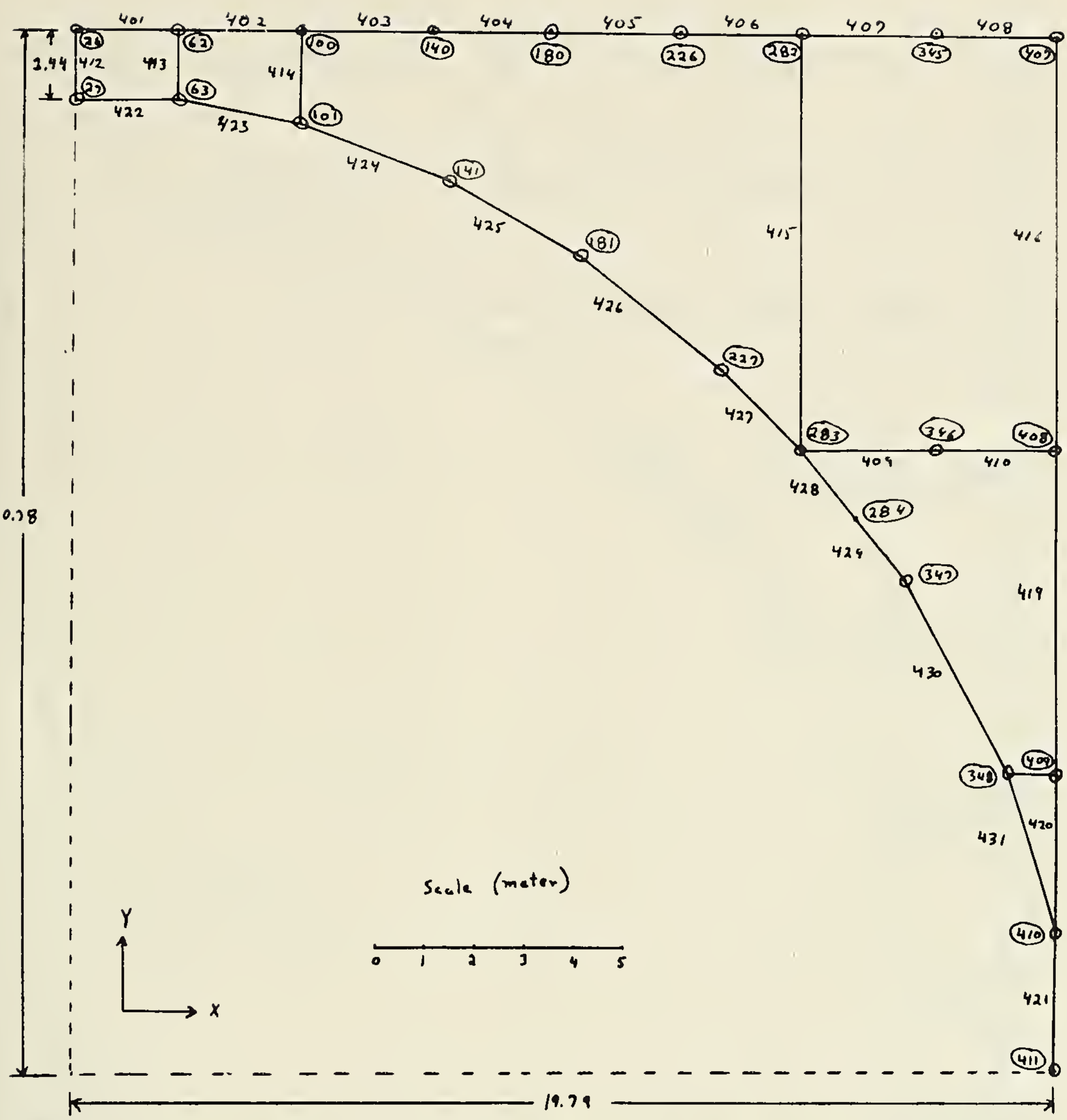
(10) joint number

10 member number

⌖ indicates that a vertical member goes up from the joint

FIGURE 10

THIRD DECK OF BEAM MODEL



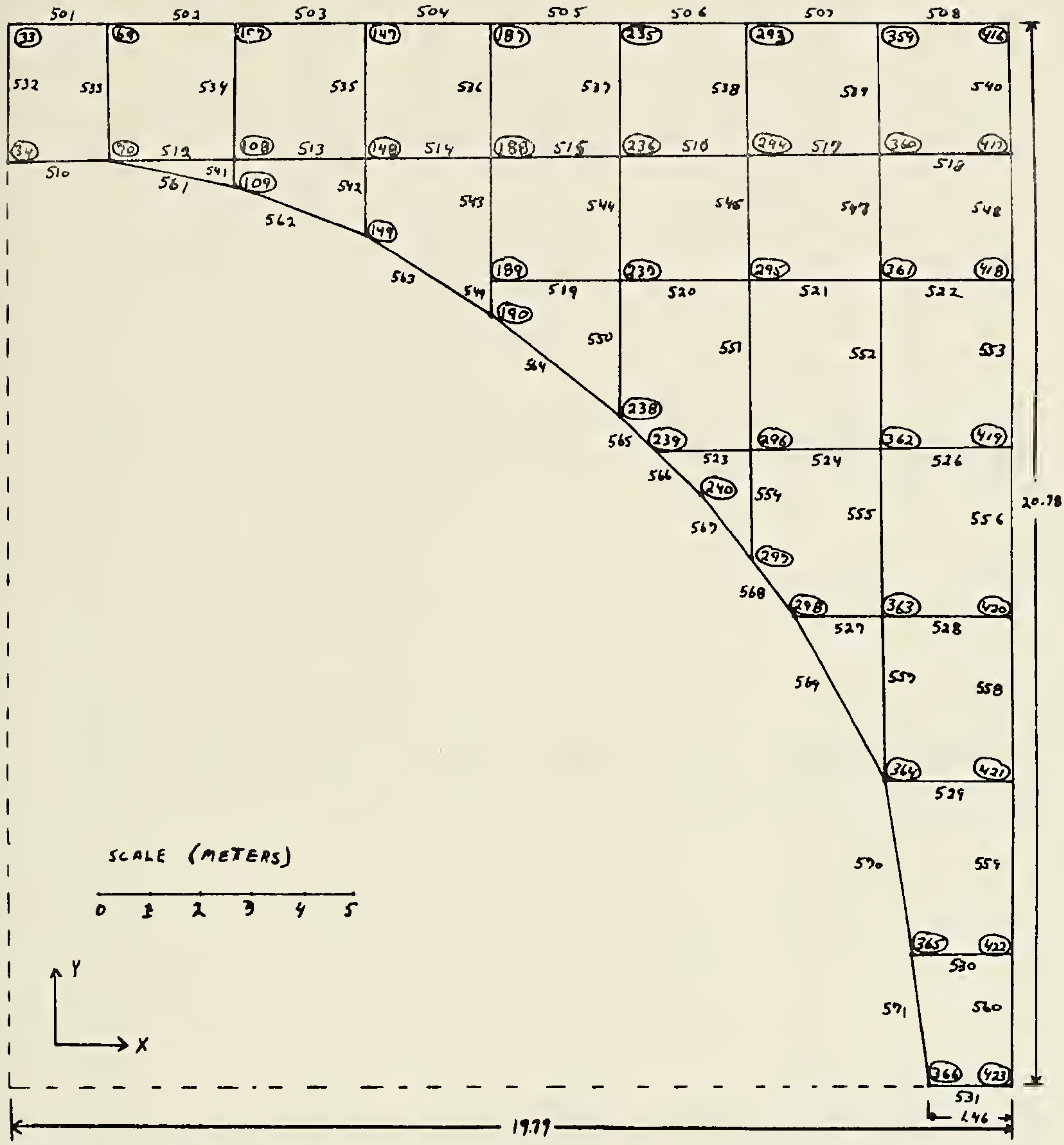
10 joint number

10 member number

indicates that a vertical member goes up from the joint

FIGURE 11

FOURTH DECK OF BEAM MODEL

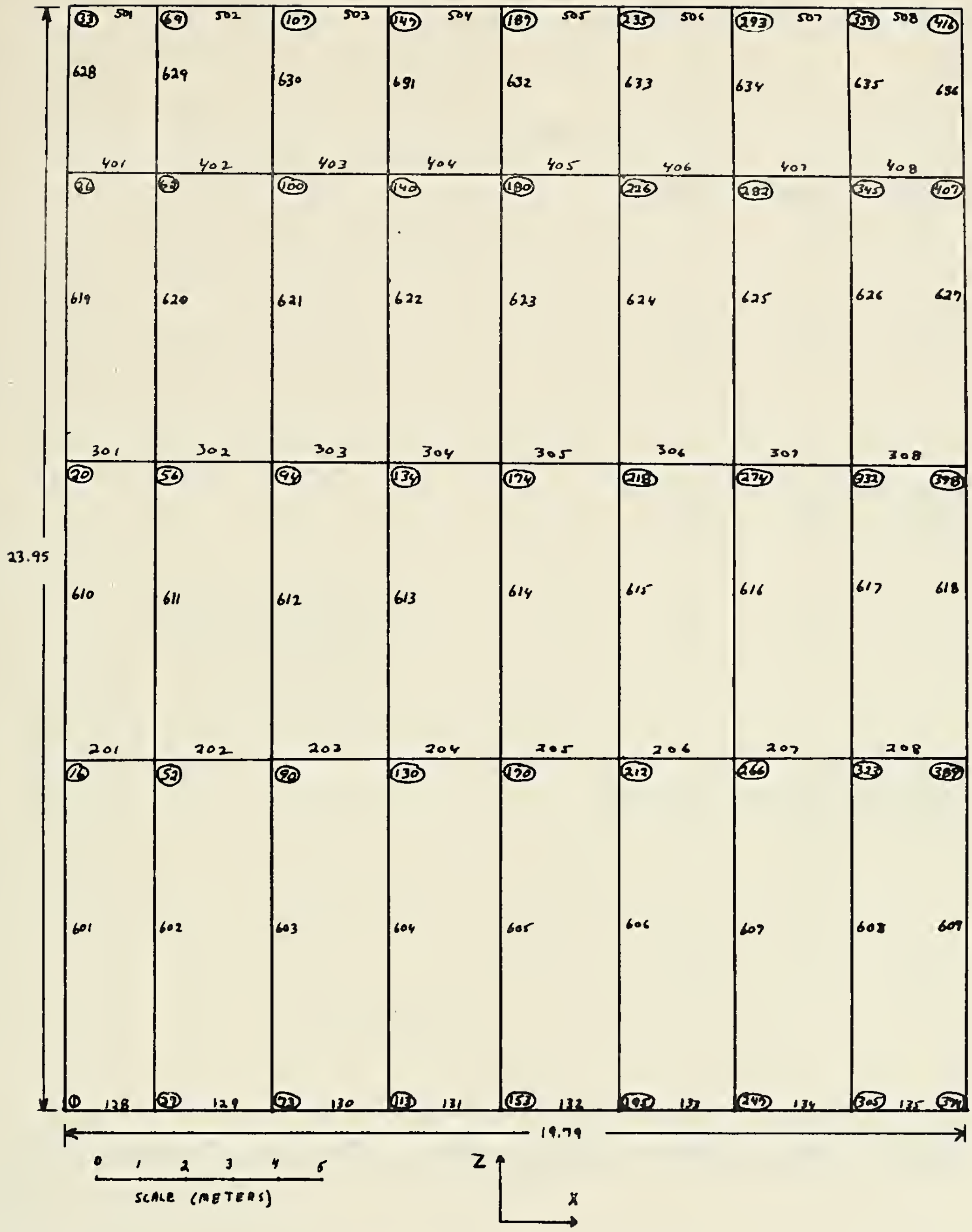


(10) joint number

10 member number

FIGURE 12

MAIN DECK OF BEAM MODEL

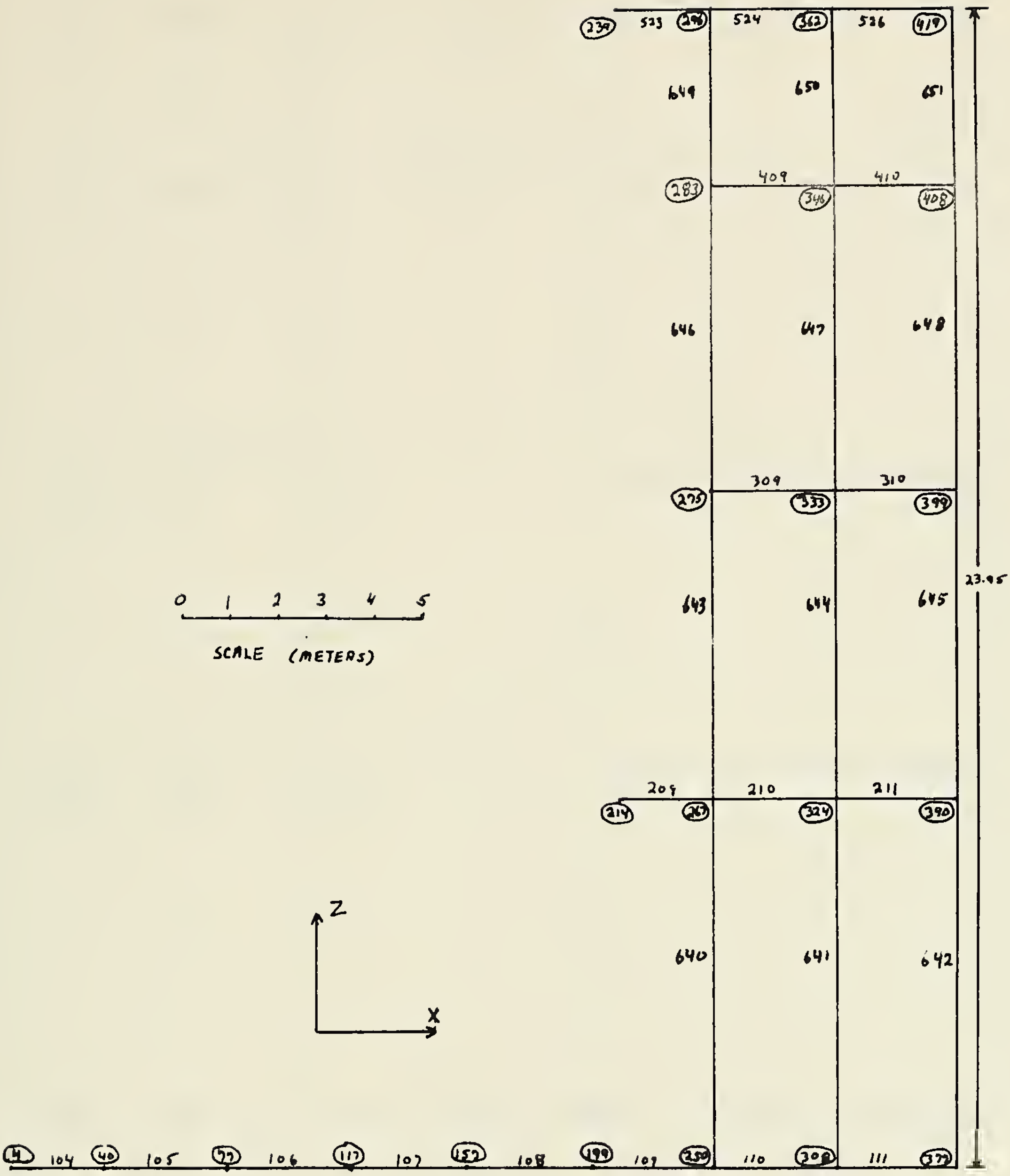


(10) joint number

10 member number

FIGURE 13

OUTER SKIN OF BEAM MODEL

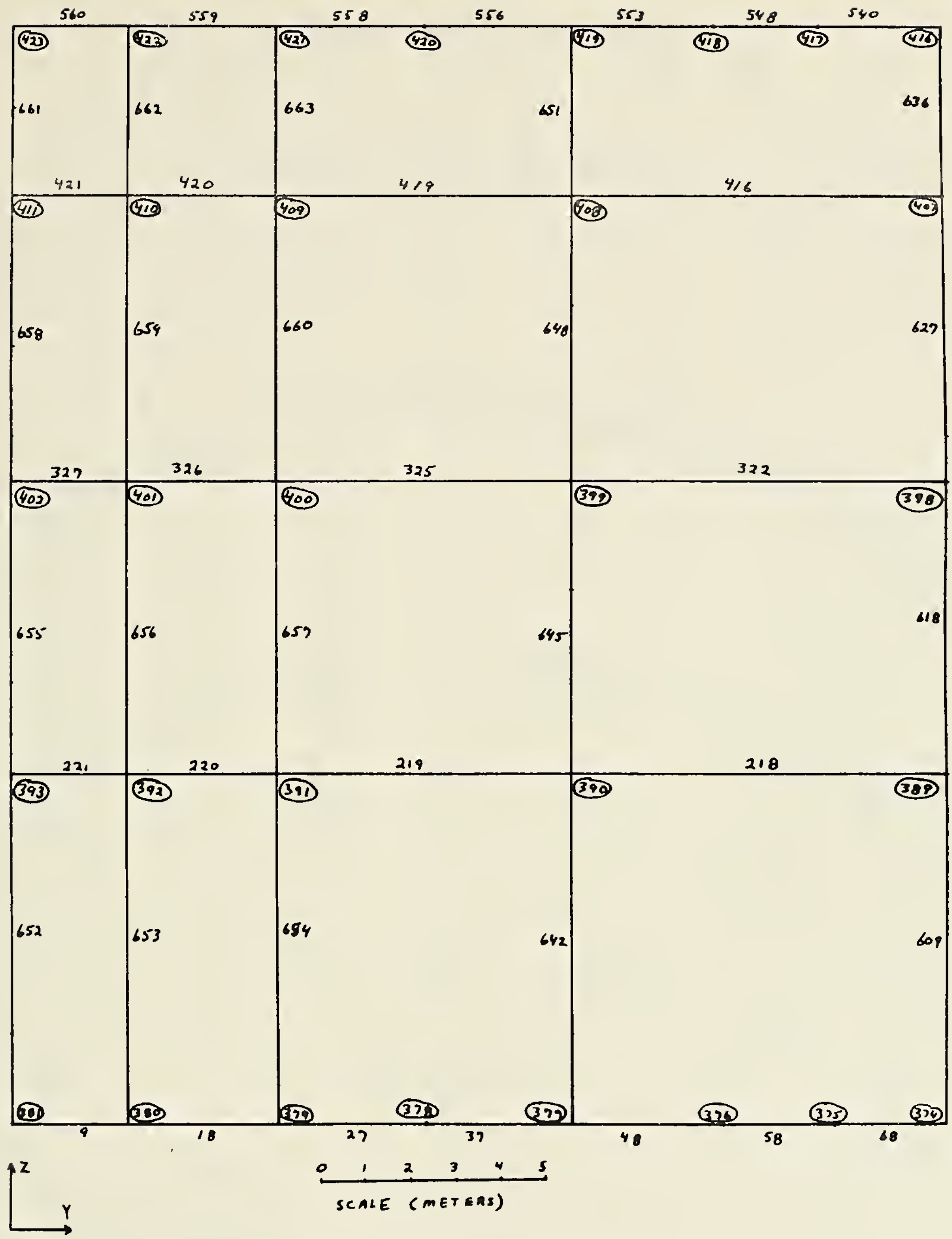


(10) joint number

10 member number

FIGURE 14

INNER WEB BULKHEAD OF BEAM MODEL

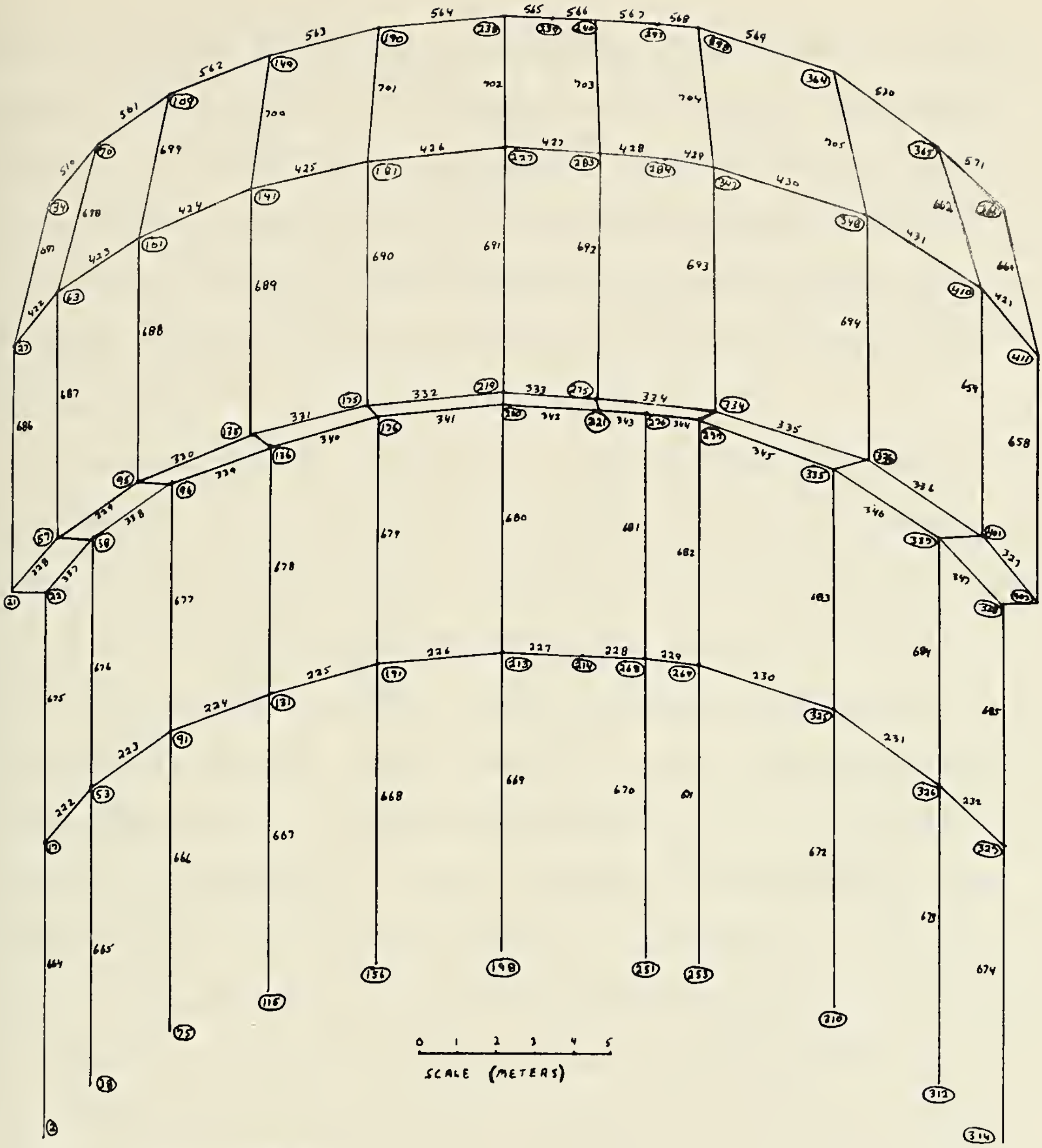


(10) joint number

10 member number

FIGURE 15

TRANSVERSE SECTION AT FRAME 195



(10) joint number

10 member number

FIGURE 16

PROJECTION OF TANK HOLD

beam and depth. This point is illustrated by the following example. The depth of the ship is 26.0 meters. The scale depth of the model is 23.95 meters. This is caused by the fact that the neutral axis of the double bottom beams are 1.15 meters from the bottom plating and the neutral axis of the beams modeling the main deck are .90 meters down from the main deck.

The location of the average neutral axis was used as the location of all the neutral axes of the beam elements that would be located in a straight line on the actual ship. This can be best illustrated using the outer web frames where the thickness of the shell plating changes as the height is increased. This change in plate thickness causes the neutral axis of each beam element to shift slightly. The member properties of the individual members were calculated using their own neutral axis. However, in assembling the model geometry, the average neutral axis was used allowing the members to lie in a vertical straight line.

There are disadvantages to using the beam model that was outlined in the preceeding paragraphs. One disadvantage is that the beam elements are connected at the joints by a point. The actual area of connection however may extend a considerable distance from the point that results from the intersection of the neutral axis. This is especially true when plates are being modeled as beams which was the case with this model. The other principal disadvantage of this

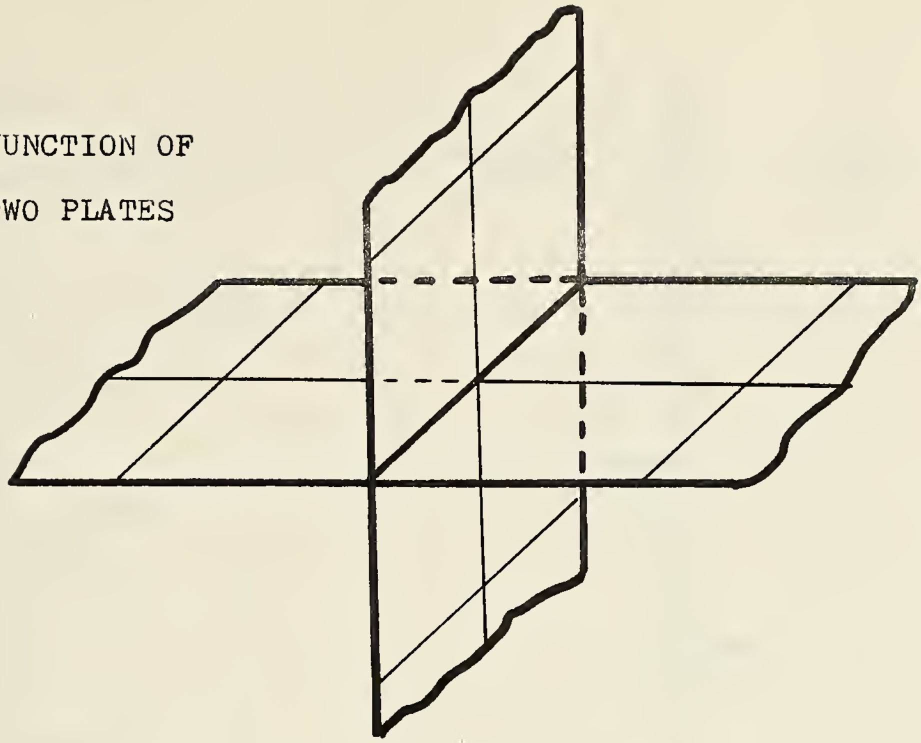
model was the result of modeling two actual decks as a single deck. This would cause a vertical beam that had a support at each end to be modeling a member that actually was supported at three places along its length. Along the same line a vertical member that is subjected to a uniform or linear force would only be supported at the ends while the actual member would be supported in at least three places. The result of these two disadvantages would be that the local bending stresses in the individual members would be inaccurate. Figures 17 and 18 illustrate these two disadvantages of the beam model.

However, it should be pointed out that these disadvantages would only affect local bending stresses to any great extent. Overall results, such as joint displacements and longitudinal stresses, would be virtually unaffected. In addition the bending stresses that resulted from this model would give an indication of areas that should be looked at more closely—possibly with a fine mesh finite element model of that small area using the results of this beam model to determine the boundary conditions.

The geometric model was entered in the STRUDL program by first numbering each joint and giving its coordinates in the global X Y Z space. The orientation of the members was determined by the coordinates of the joints that were its end points. Each member has a local coordinate system associated with it for the easy identification of input and

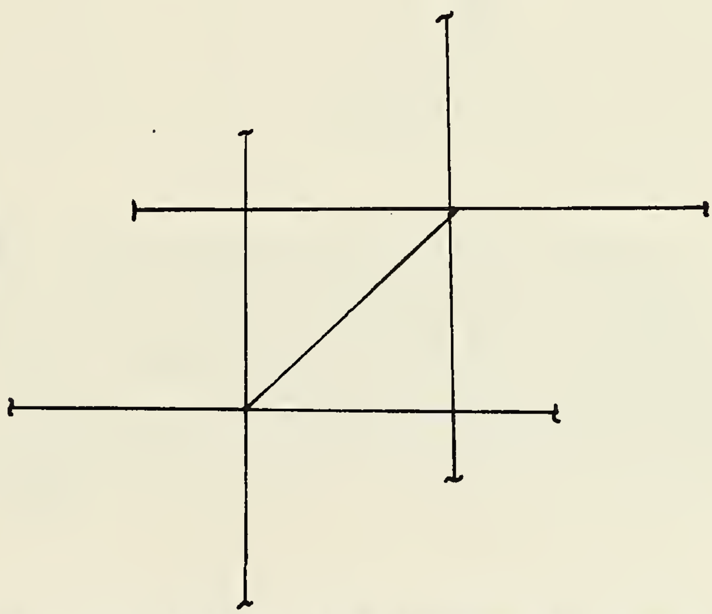
JUNCTION OF

TWO PLATES



BEAM MODEL

OF ABOVE FIGURE



The light lines in the top figure indicate material from which the member properties of the beams were calculated. The bending of the vertical plate about the Y axis is not accurately modeled by the two vertical beams since the junction is actually a straight line and in the model it consists of two points.

FIGURE 17

MODELING ILLUSTRATION

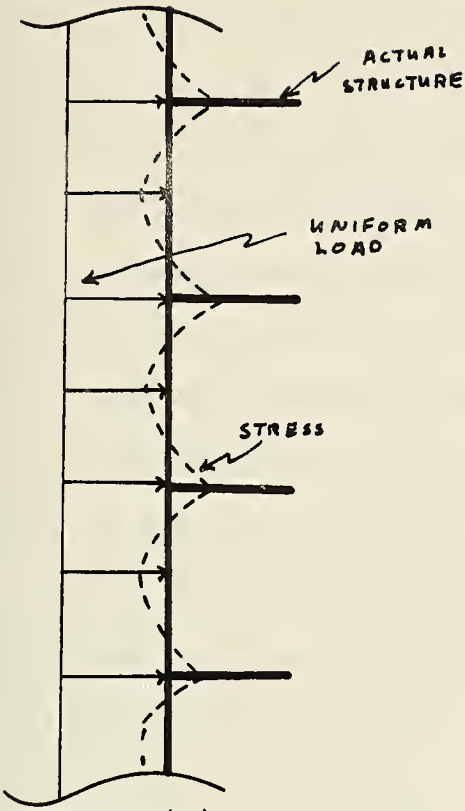


FIGURE (A)

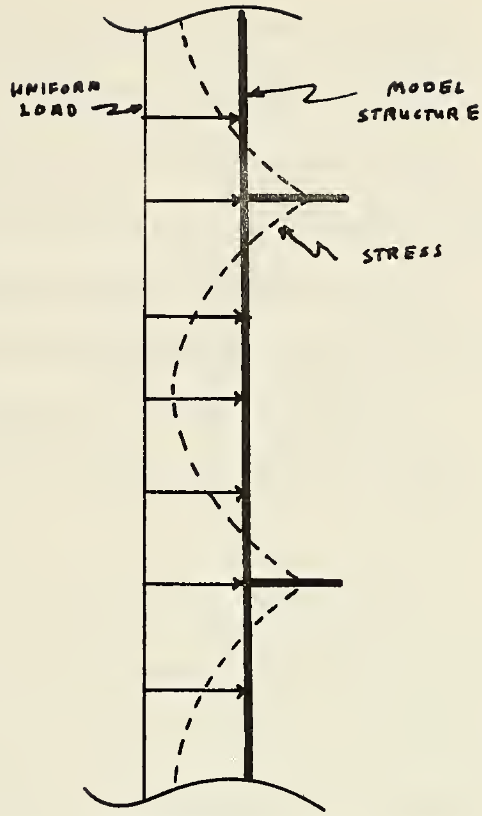


FIGURE (B)

Figure (A) shows a beam supported at four points with a uniform load applied. Figure (B) illustrates how the same structure would be modeled. As can be seen by the dashed line showing the relative magnitude and sign of the bending stresses, the model gives a local bending stress that does not represent the actual case. However when the deflections of the joints are considered the modeling is accurate since a single beam of the model would have a strength equivalent to two of the actual beams.

FIGURE 18

MODELING ILLUSTRATION

output. The local positive x axis goes from the starting joint to the end joint. The one remaining degree of freedom for the member was rotation about the principal axes. This last degree of freedom was specified by the angle beta. The reference position for the beta angle (beta = 0) is with the local axis z in the same direction as the global Z axis and with the local axis x parallel to the global Y axis. The method of determining the beta angle for other cases is outlined in Reference 7.

There were many locations on the actual ship where additional stiffners were added to the shell plating between structural members. To account for their effect the prismatic cross-sectional area of these stiffners were "blended" into the plate to produce an effective plate thickness (Sample Calculation 1).

It was not necessary to determine the effective width of plating for any of the members since no buckling of any member was anticipated. However, it was necessary to determine the effective breadth of the various beams, both in the y and z directions in order that a realistic moment of inertia and section modulus could be calculated for each of the local member coordinates.

Originally the plan was to determine the effective breadths using Schade's curves (Ref. 13 and 14). However, the use of these curves required knowledge of the loading conditions prior to the calculation of member properties.

The intention of this work was to do several loading conditions, (loaded, ballasted, hogging, sagging, etc.) and it would have been completely infeasible, time wise, to go back and recalculate the member properties of all the beams for each loading condition. Instead, the standard design criteria for mild steel was used where the effective breadth of plating was equal to sixty times the plate thickness. This criterion results from the fact that the effective breadth of plating acting in association with a structural member, is influenced by the yield strength and the modulus of elasticity of the material (Ref. 11). This influence can be calculated by the formula

$$\text{effective breadth} = 2\sqrt{E/F_y}\ t$$

where E = modulus of elasticity (psi)

F_y = tensile yield strength

The above design criteria results from the fact that $2\sqrt{E/F_y}$ equals 60 for mild steel.

STRUDL requires that the cross-sectional axis, the torsional rigidity coefficient, and the moments of inertia about the local y and z axes be specified for the stiffness analysis of a space frame. Since the sectional stresses in the members were desired it was also necessary to specify the section moduli about the local y and z axes. The shear areas in the Y and Z directions were also supplied in order that the analysis would also include shear deformations.

A computer program was written to calculate the above member properties to avoid tedious and repetitive hand calculations. The program was capable of calculating the member section properties of prismatic beams of five or fewer elements. The procedures used by the computer program are illustrated by an example in Sample Calculation 2.

The beam element model was constructed in such a way that it could be expanded to handle non-symmetrical loadings about the center, or in other words, the expanded model would be capable of handling the case when the ship is in a heeled position. The final quarter tank section model was a space frame consisting of 414 beam members and 208 joints.

Information that was requested as output from the STRUDL program was: (1) the forces acting on both ends of the member, (2) the reactions at support joints, and (3) the displacements of each joint. In addition section stresses of the members were requested for each end and the center of the member. The section stresses were broken down into axial and bending stresses from which the maximum and mimimum normal stresses were calculated. The shear stresses at the three sections were calculated by dividing the shear forces by the shear area.

THE ANALYSIS—HOGGING CONDITION

General Discussion

The first case to be investigated was with the ship in an upright position, fully loaded with the wave crest amidships, the trochoidal wave used by Technigaz to compute the shear and bending moment curves had a length equal to the ship's length-between-perpendiculars which was 275 meters. The wave height was equal to 0.03 of the wave length or 8.4 meters. The depth of water at frame 228 was then calculated by adding the wave height to the stillwater draft. The Smith effect was also included in these calculations.

An interesting load curve results when a ship carries cargo in large spherical tanks as with this ship. The spherical tank is supported at various points around its equator, thus the loads are transmitted to the hull of the ship in a circle. The load curve would then have extremely high loads per unit length in the areas where the tanks are adjoining and, fairly low loads in the area of the transverse centerlines of the tanks. Thus, for this particular ship the load curve would have high spikes at frames 61, 129, 195, 261, 327, and 389. This loading curve cannot be accurately approximated by a series of straight lines indicating a uniform load over a certain segment of the vessel's length as is the normal design practice. The load curve for this particular type of vessel must be either accurately

plotted and a graphical solution obtained or some type of curve-fitting computer solution performed.

The shear and moment curves provided by Technigaz were calculated using the dynamic weight of the cargo. The dynamic loads in this region were calculated by determining the vertical accelerations at tank 3. The vertical acceleration included the acceleration due to gravity, heave accelerations and pitch accelerations, the total of which was 13.21 meters/second. These accelerations were determined from Series 60 data that gave results indicating a heave of ±7 meters in 10.0 seconds and a pitch of ±5.7 degrees in 10.0 seconds. The dynamic force was then calculated by multiplying the mass of the tank and LNG times the ratio of the total acceleration to the acceleration of gravity. This ratio, which was the number of "g" forces felt at tank 3,was 1.4. The resulting dynamic load due to the tank and cargo was 20,200 metric tons.

Information supplied by Technigaz indicated that the steel weight, excluding the spherical tank, was 6,472 metric tons between frames 195 and 261, the area of interest. A quarter tank section then had a steel weight of 1,618 metric tons.

The only additional forces that had to be applied to the model were the boundary forces which will simulate the remainder of the ship. As is indicated by Figure 19, the after portion of the ship may be simulated by the applica-

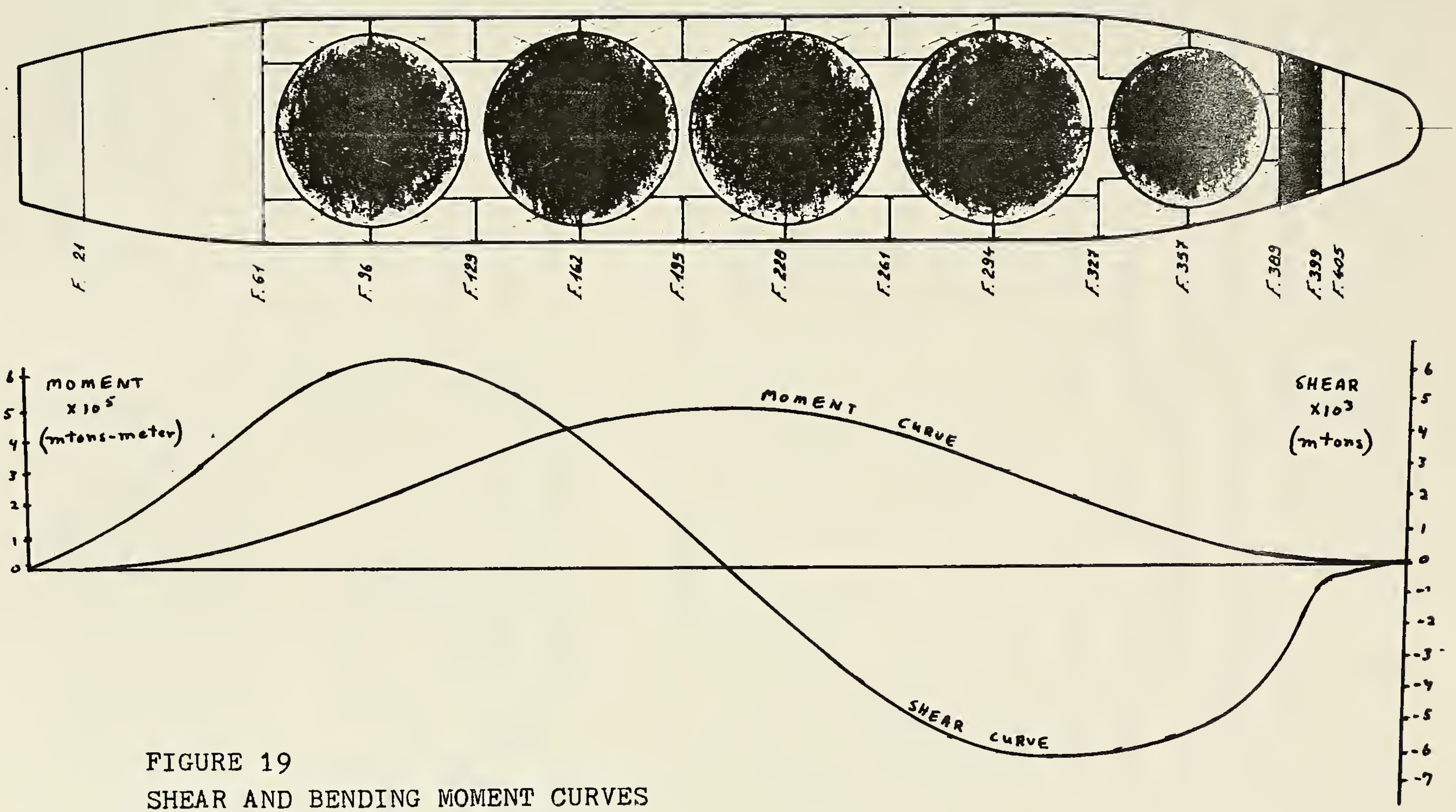


FIGURE 19
SHEAR AND BENDING MOMENT CURVES
FULLY LOADED HOGGING CONDITION

tion of a bending moment of 484,940 meter-tons and a shear force of 1,221 tons at frame 195, the free end. In addition it was necessary to apply a shear force at frame 228, the transverse plane of symmetry, of such sign and magnitude as to maintain the model in rigid body equilibrium. Or, in other words, it is necessary that the sum of the forces in the Z direction be equal to zero. An alternative method used by some investigators in this field to insure rigid body equilibrium is to fix the support joints in the transverse plane of symmetry in the Z direction. This method is not satisfactory in this particular case since knowledge of deflections of the members is the primary reason for the analysis and for this particular ship there are large Z direction deflections in the plane of symmetry.

First Run—Loads

The beam model was to be subjected to basically four different types of forces. These were boundary conditions, loads due to water acting on the hull, loads due to the cargo, and loads due to the steel hull weight. The question was, how should the various forces be distributed to accurately represent the actual case.

The actual steel weight of the quarter section of the model was distributed equally among the joints with a joint load of 7.78 metric tons in the negative Z direction. This was considered a valid distribution since there were a

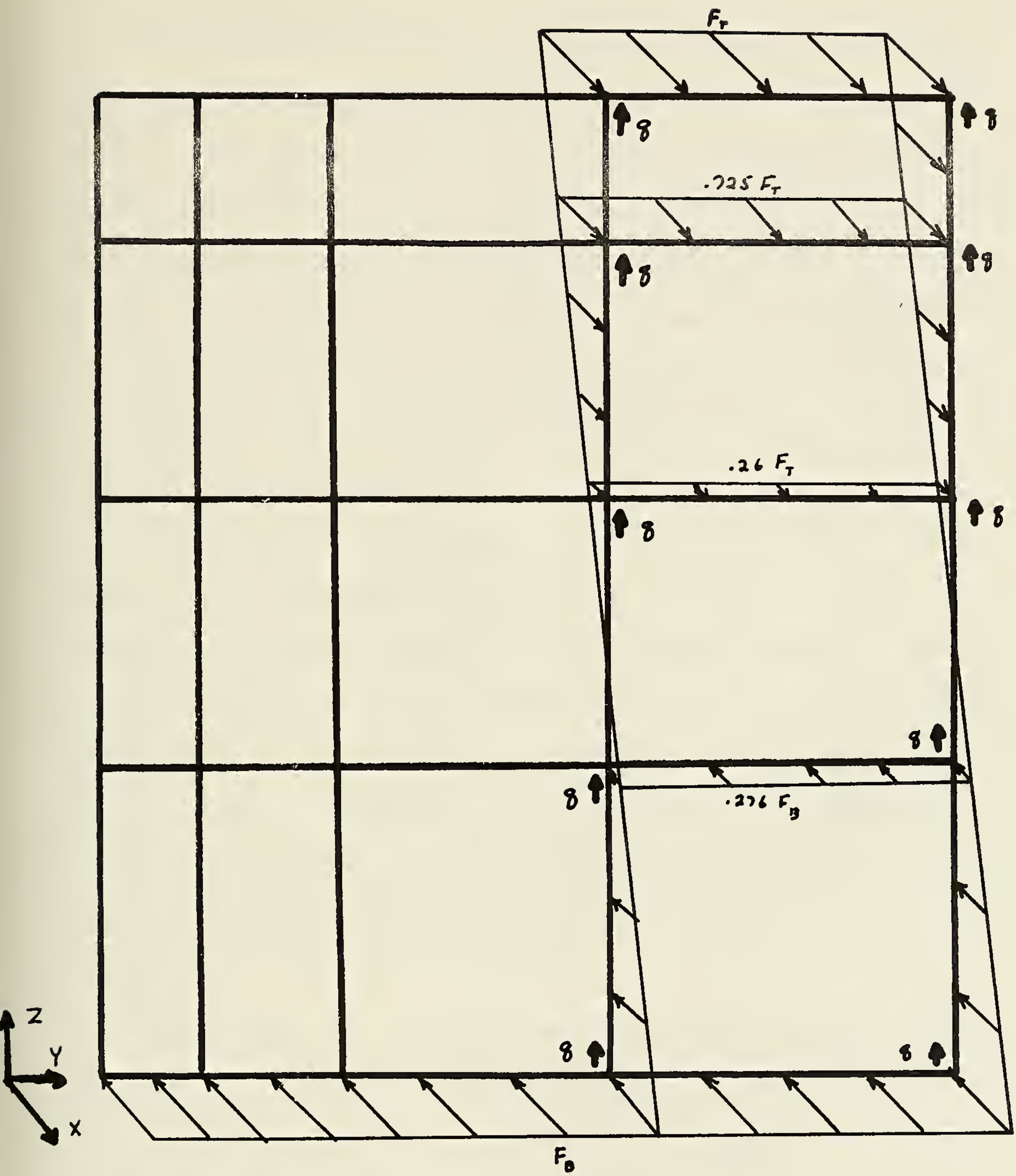
greater number of joints in locations where there was a large amount of structural steel. The concept of a uniform force in the negative Z direction applied to each member was completely infeasible from the standpoint of additional programming and computer time required, although, this would have been the ideal solution.

The dynamic load of the cargo was 20,200 metric tons of 5,050 tons per quarter tank section. This load was applied as a joint load at each of the vertical members of the support platform (third deck of the model). The load was equally distributed among the joints resulting in a load of 505.0 tons at all the joints except joints 22 and 338 which were in the planes of symmetry and consequently had one half the applied load of the other joints or 252.5 tons. Sample Calculation 3 illustrates the method of calculation of the applied loads.

The forces due to the water acting on the bottom and side of the hull were calculated as if the depth of the water remained constant over the entire quarter tank section. This assumption was slightly in error in that the depth was slightly less at the ends of the model due to the fact that the wave crest was near the center of the model. However, it was felt that this effect was negligible due to the trocoidal nature of the wave crest. The forces on the side of the ship were idealized as linearly varying loads on the vertical members. The bottom forces were applied to the

model as uniform forces—half of the total bottom forces were applied to the longitudinal members and half to the transverse members. A ratio of ship dimension to model dimension was used in the calculation of these forces so that the force actually experienced by the ship is applied to the model.

The remaining loads to be applied were the boundary conditions. The bending moment of 484,940 meter-mtons at frame 195 was simulated by coupled forces. The neutral axis of the model at this point was calculated to be about 10.5 meters from the double bottom. Above the neutral axis a uniform load was applied in the positive X direction to the main deck between the inner and outer web frames. In addition a linear load was applied to the inner and outer web bulkheads from the main deck to the neutral axis, with the third and fourth decks carrying a uniform load equal to the value of linear distribution at the intersection of the webs and deck members. The other half of the couple was applied below the neutral axis in the negative X direction. This was accomplished by imposing a uniform load across the entire half width of the double bottom, with a linearly decreasing load on the webs, starting at the double bottom up to the neutral axis. The second deck carried a uniform load equal to the linear load applied to the web at its joints. See Figure 20 for a graphical representation of the distribution.



F_t = 4.042 mtons/cm
F_b = 4.063 mtons/cm
q = 61.05 mtons

FIGURE 20
FRAME 195 BOUNDARY CONDITIONS
HOGGING CONDITION—RUN I

No forces were applied to members nearer the centerline than the inner web with the exception of the double bottom. The reason for this was that structural members do not contribute to the longitudinal strength of the vessel due to their discontinuous nature in way of the holds for the spherical tanks. The inner web was the structural section that was closest to the centerline of the vessel and maintained its longitudinal continuity although it did form part of the tank hold.

The shear load at frame 195 was 1,221 mtons or 610.5 mtons for the quarter tank section. This was equally distributed as a joint load of 61.05 mtons to each of the 10 joints that lie in the intersections of the plane of frame 195 and the inner and outer bulkheads of the wing tanks. No shear force was applied to the vertical bulkheads near the centerline because of their large lightening holes and poor vertical strength when compared to the inner and outer web bulkheads.

The remaining boundary condition is the shear force at frame 228. This force was determined by summing the vertical forces applied to the model. The negative of this summation then gave the force necessary to keep the model in equilibrium. For this particular loading condition this force was a negative 1,389 mtons which was distributed as joint loads at nodes in the inner and outer web bulkheads at frame 288. See Figure 21.

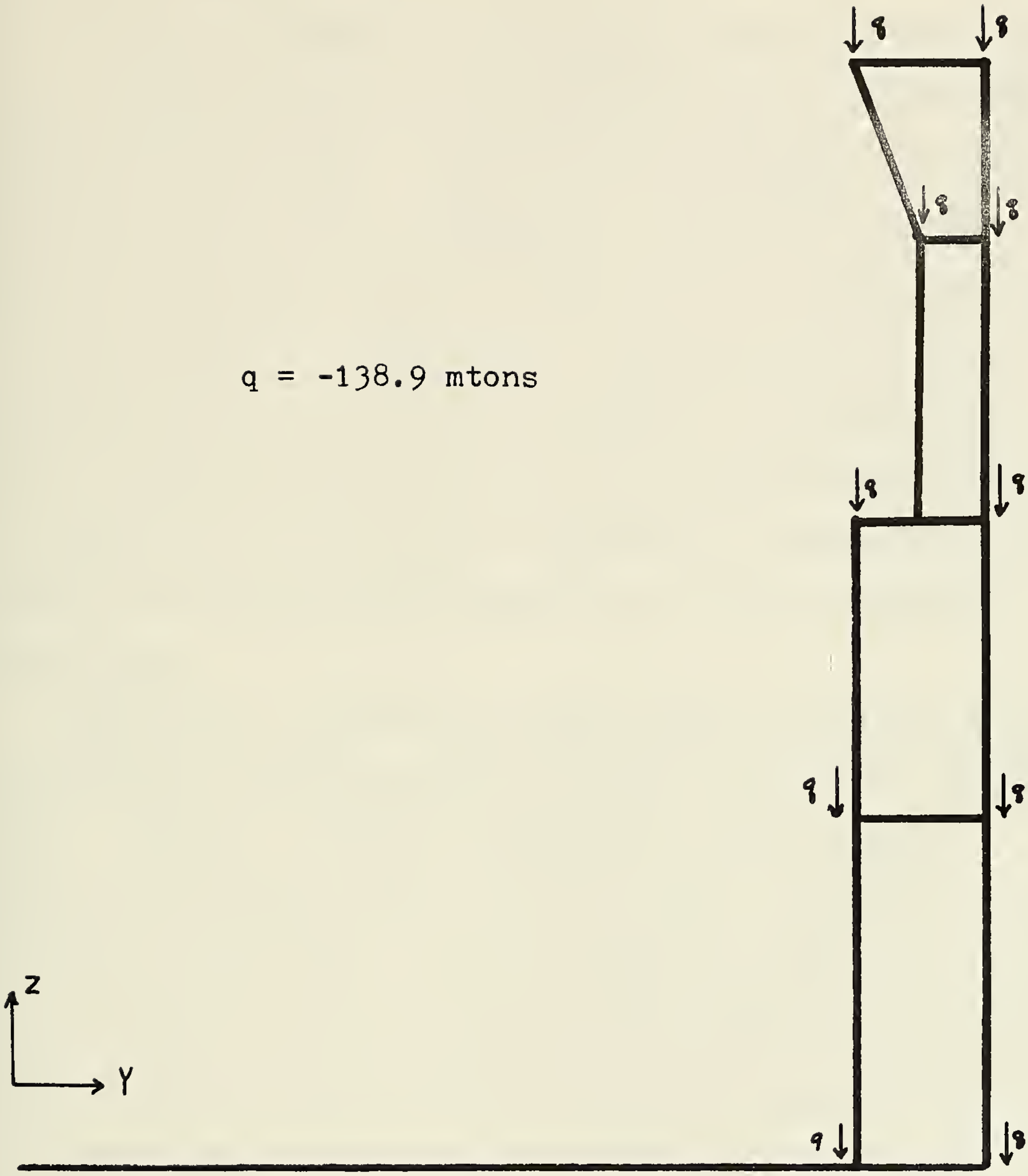


FIGURE 21

FRAME 228 BOUNDARY CONDITIONS

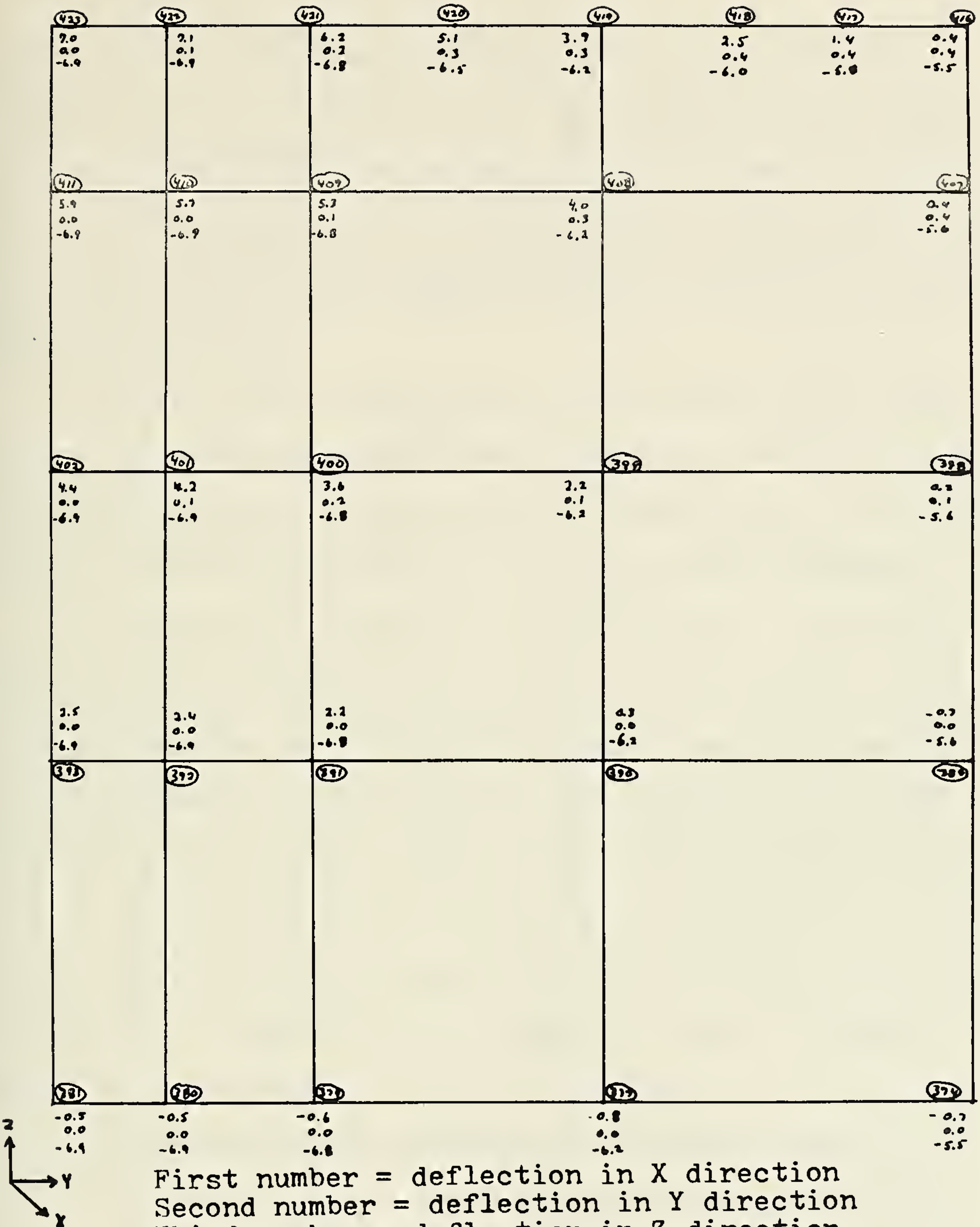
HOGGING CONDITION—RUN I

First Run—Results

The first attempts to get results from this model were unsuccessful due to the large amount of core and facilities required by the model. Some of the subprograms that make up STRUDL have job control statements inherent in them that allow for a certain number of disks to be in operation when that subprogram is being used. This particular model required more discs than were provided by the subprogram. Thus it was necessary to enter input statements which overrode some of the job control statements of some of the subprograms and allowed the computer to utilize sufficient facilities.

Results for the first run were finally obtained and the deflections appeared satisfactory when looked at on a macro-scale. However, a closer examination of the section stresses indicated several problem areas. A major problem occurred at frame 195. The deflections of the fourth deck at the inner web in the positive X direction were large over a beam length as indicated by Figure 22. This resulted in all members eminating from joint 408 to have extremely high bending stresses. Furthermore, this large deflection in the X direction was transmitted to the circular hold bulkhead at joint 283 causing the circular support platform to elongate with resulting high stresses in all members in the vicinity.

The elongation of the circular hold acting in conjunction with the water forces on the side of the ship, caused a



First number = deflection in X direction
Second number = deflection in Y direction
Third number = deflection in Z direction

FIGURE 22

DEFLECTIONS OF FRAME 195

HOGGING CONDITION—RUN I

deflection in the negative Y direction of the circular support platform bulkhead at the narrow area of the ship's hull near the transverse centerline of the tank (frames 216 to 228). This effect was most pronounced at the second deck level and caused high bending stresses in the vertical members in this area.

A second major problem area was the main deck, again at the narrower sections between frames 219 and 228. High stresses occurred in the horizontal members due to the high axial stresses combined with the high bending stresses.

The third major problem area occurred in the double bottom at the junction of the double bottom and the vertical strength members of the support platform again in the vicinity of frame 228. The joints at this junction had large negative Z deflections, which caused large bending stresses.

A fourth problem area was in the vicinity of the origin in the double bottom. Members eminating from the origin had a positive Z deflection for a radius of about 6 meters instead of the expected negative deflection.

Figures 23 and 24 show the longitudinal stress distribution at frames 195 and 228 respectively. Approximately 25 per cent of the members of the model had total normal stresses that exceeded the yield stress of mild steel. At this point a complete review of the model and all calculations was undertaken.

The first discovery was that an error of about 5 per

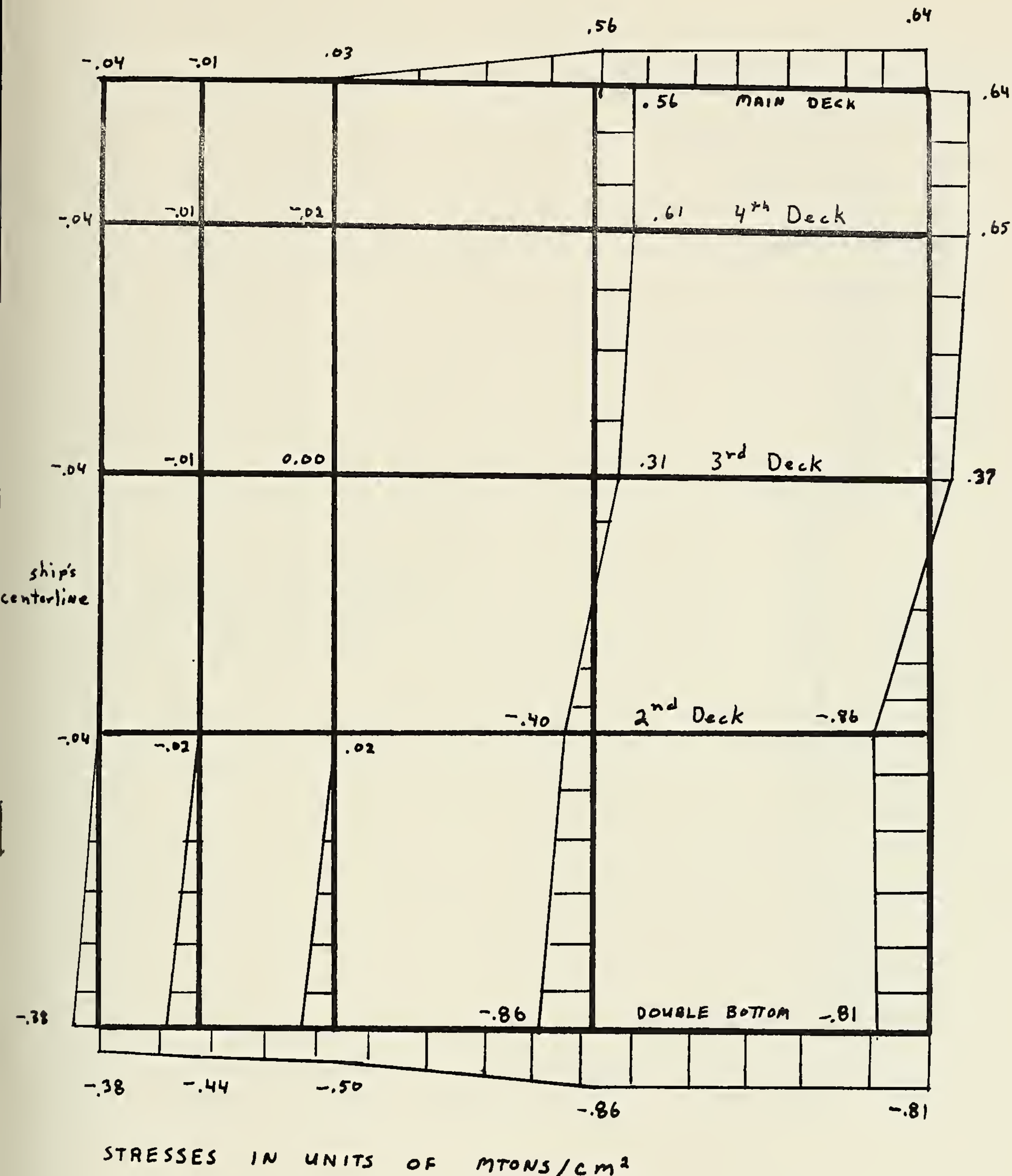


FIGURE 23

LONGITUDINAL STRESSES—FRAME 195

HOGGING CONDITION—RUN I

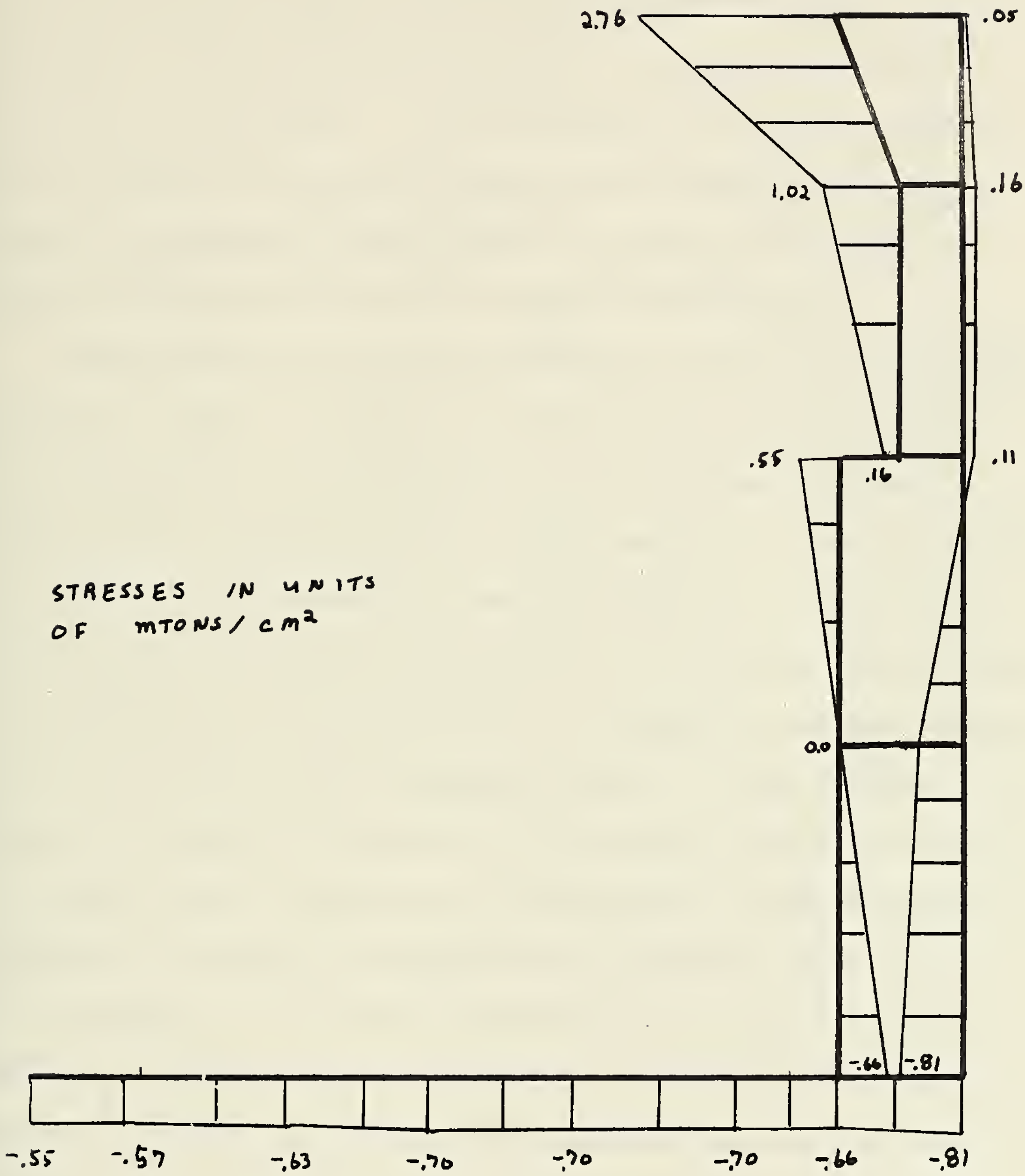


FIGURE 24

LONGITUDINAL STRESSES—FRAME 228

HOGGING CONDITION—RUN I

cent had been made in the calculation of the bottom water pressure forces acting on the longitudinal members. This resulted in the fact that the sum of the forces in the Z direction was not zero. This imbalance in forces caused a small amount of rigid body motion which would then have caused the unexpected deflections in the vicinity of the origin outlined above as the fourth problem area.

Conversation with representatives of American Technigaz brought to light the fact that the dynamic weight of steel had been used in the calculation of the shear and bending moment curves instead of the static weight. This factor had not been taken into account for the first run. This correction would increase the negative Z direction joint loads that simulated the steel weight. A summation of the forces in the Z direction then indicated that the shear force required at frame 228 to prevent rigid body motion could then be reduced from 1,389 mtons to 742 mtons. Consequently, correction of this error would help solve the problem of high stresses in the double bottom at the intersection of the double bottom and the vertical members of the circular support platform which was described earlier as problem three.

It was obvious that the extreme elongation of the circular hold and the inconsistent X direction deflections in frame 195 were caused by the boundary forces that were used to simulate the bending moment. Thus it was necessary to

determine whether the distribution of forces that was used was correct and if not, what was the correct distribution. Obvious methods, such as building a plastic scale model of two or three sections of the ship, loading the model and getting the longitudinal stress distribution at frame 195, were considered. Another method that could have been used to obtain the desired information was a large macro-mesh model consisting of plate elements which could be developed using the finite element capability of STRUDL. These two methods of solution had to be discarded because of time considerations. A literature search was then conducted to try to find longitudinal stress data from experiments using plates with circular cutouts.

Papers were found in which experiments had been performed on plates subjected to a uniform tension force at its ends with a series of circular cutouts in which the cutouts had been reinforced with a combing. This would have approximated very closely the main deck of this ship. However, the papers that contained this work only presented stress results for a transverse section through the center of the circle. This is understandable since the highest stresses would occur at this point. No information regarding the stress distribution in other parts of the plate was provided.

The only information that was readily available was Kirch's solution for a central circular hole in an infi-

nitely wide plate subjected to a pure tension stress (Ref. 5). The results of his solution were:

$$\sigma_r = \frac{\sigma}{2} \left(1 - \frac{r_o^2}{r^2}\right) + \frac{\sigma}{2} \left(1 - 4 \frac{r_o^2}{r^2} + 3 \frac{r_o^4}{r^4}\right) \cos 2\theta$$

$$\sigma_\theta = \frac{\sigma}{2} \left(1 + \frac{r_o^2}{r^2}\right) - \frac{\sigma}{2} \left(1 + 3 \frac{r_o^4}{r^4}\right) \cos 2\theta$$

where σ = tension stresses to which plate is subjected

σ_r = radial stresses

σ_θ = tangential stresses

r_o = radius of hole

r = radius at which calculation is being made

θ = angle r makes with longitudinal line through center of the circle

Subsequent to the calculation of the radial and tangential stresses through a transverse section 20.34 meters ahead of the center of the circle it was possible to calculate the distribution of the longitudinal stresses by the equation:

$$\sigma_x = \sigma_r \cos\theta + \sigma_\theta \sin\theta$$

where σ_x = longitudinal stress

The result of the calculations utilizing the above equations is shown in Figure 25 with the stresses indicated as a fraction of the stress at what would be the edge of the

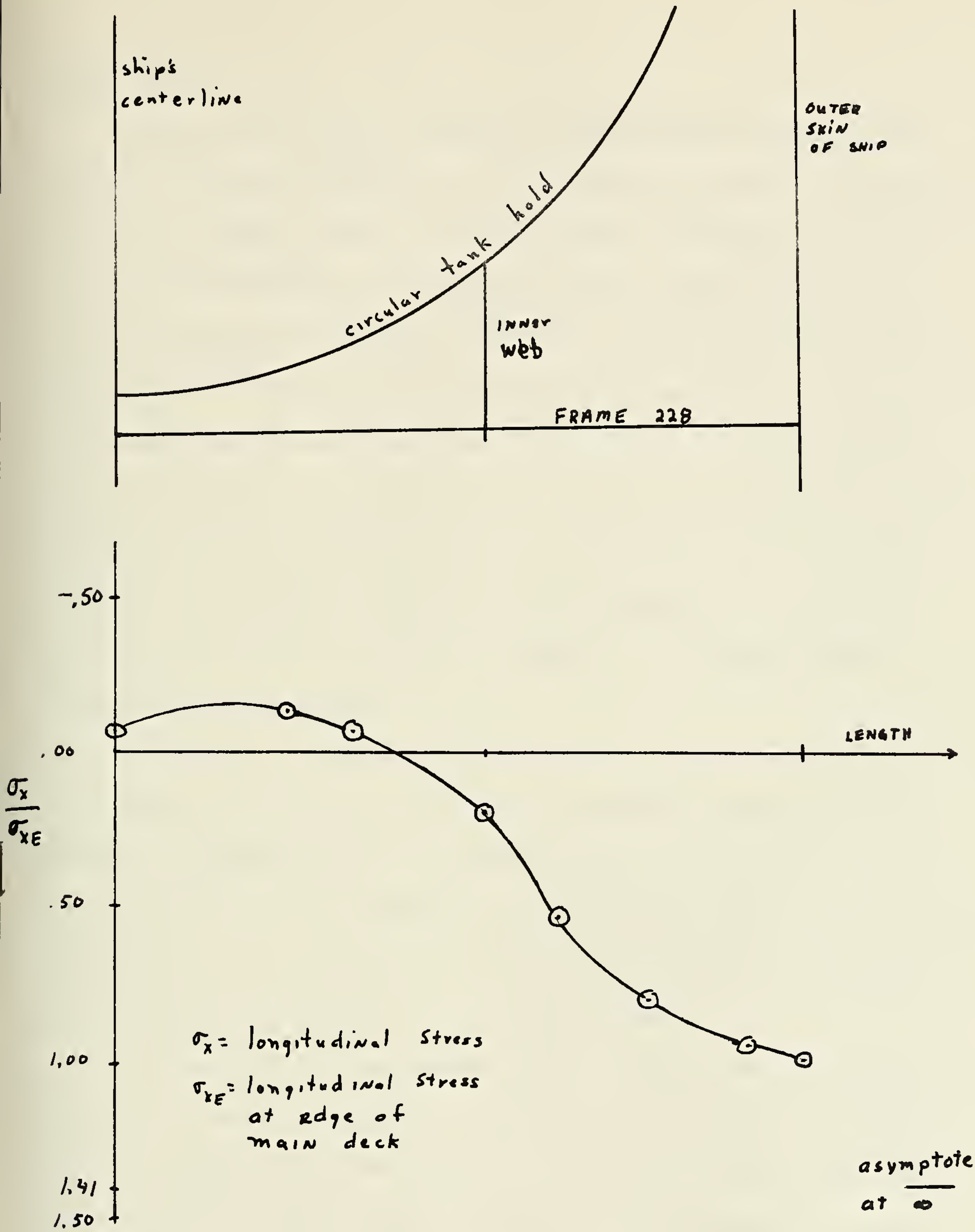


FIGURE 25

LONGITUDINAL STRESS DISTRIBUTION IN MAIN DECK CALCULATED ACCORDING TO KIRSCH'S SOLUTION FOR AN INFINITE PLATE

main deck.

There are several important differences between the actual main deck plating and the idealized plate with the circular cutout. First, in the actual situation the main deck is not infinite in the horizontal plane as was the above solution. Secondly, Kirsch's solution did not take into account the fact that the actual case had an inner web bulkhead running longitudinally or that it had a vertical wall around the circumference of the hole. In addition the solution for the infinite plate with the single circular cutout did not take account of any change in the stress distribution that a series of holes in the longitudinal direction would cause.

In spite of the many differences between the actual main deck and the plate with the circular cutout and with no way of quantitatively determining the effects of these changes, it was felt that the calculated distribution would be helpful in determining the correct boundary conditions that should be imposed on the beam model.

It was readily apparent from a comparison of Figures 23 and 25 that, in no way, did the distribution of longitudinal stresses that was the result from the first run compare with the distribution obtained from Kirsch's solution. For example, the longitudinal stress in the plate calculation at the inner web bulkhead was 19 per cent of the load at the point corresponding to the side of the ship while the

results from the first run indicated that the stress at the inner web was 88 per cent of that at the main deck edge.

Thus it was obvious that a more realistic application of the bending moment boundary conditions was necessary to obtain any meaningful results. This new distribution of forces would have to put a greater load on the part of the main deck that is longitudinally continuous as well as a greater share on the outer hull. Such a refined approach would tend to reduce the problems encountered on the fourth deck at the intersection of the circular hold and the inner web which resulted in an extreme elongation of the circular hold. A more realistic distribution would also tend to reduce the high stresses that occurred at the narrow portion of the main deck at frame 228.

Second Run—Loads

The decision was made to run the STRUDL program a second time for the hogging condition making the changes to the loads that were necessary. The first correction made was to change the joint loads due to the ships steel weight from 7.78 metric tons/joint to 10.89 metric tons/joint. This new weight was the result of using a "g" force of 1.4 as was previously discussed. This change also made necessary a change in the shear force at frame 228. A summation of forces in the Z direction indicated that the shear force per joint should be reduced to 74.2 mtons/joint as indicated in

Figure 26. The force due to the water acting on the longitudinal members of the double bottom was also corrected for this run.

The largest problem for the second run was to determine the distribution of longitudinal forces that would accurately simulate the bending moment and give a reasonable distribution of longitudinal stresses in the main deck. After a careful reanalysis it was decided that no forces should be applied to the horizontal members making up the second, third, or fourth deck. The reason for this was that these decks had almost no longitudinal strength due to the large lightening holes in them. The elimination of forces on these members would be a conservative estimate when the ship is looked at as a whole, since the decks would assume a small portion of the longitudinal load. In order to try to obtain a longitudinal stress distribution in the main deck a linearly varying load was applied to the transverse members of the main deck of frame 195 between the inner and outer web frames. The value of the force at the inner web was half of that at the edge of the ship as indicated in Figure 27. In addition, a linear load was applied to the vertical member of the inner and outer web bulkheads, with the maximum value being the force on the main deck or the double bottom and a zero force at the neutral axis.

Second Run—Results

The results from the second run seemed much more rea-

q = 74.2 mtons

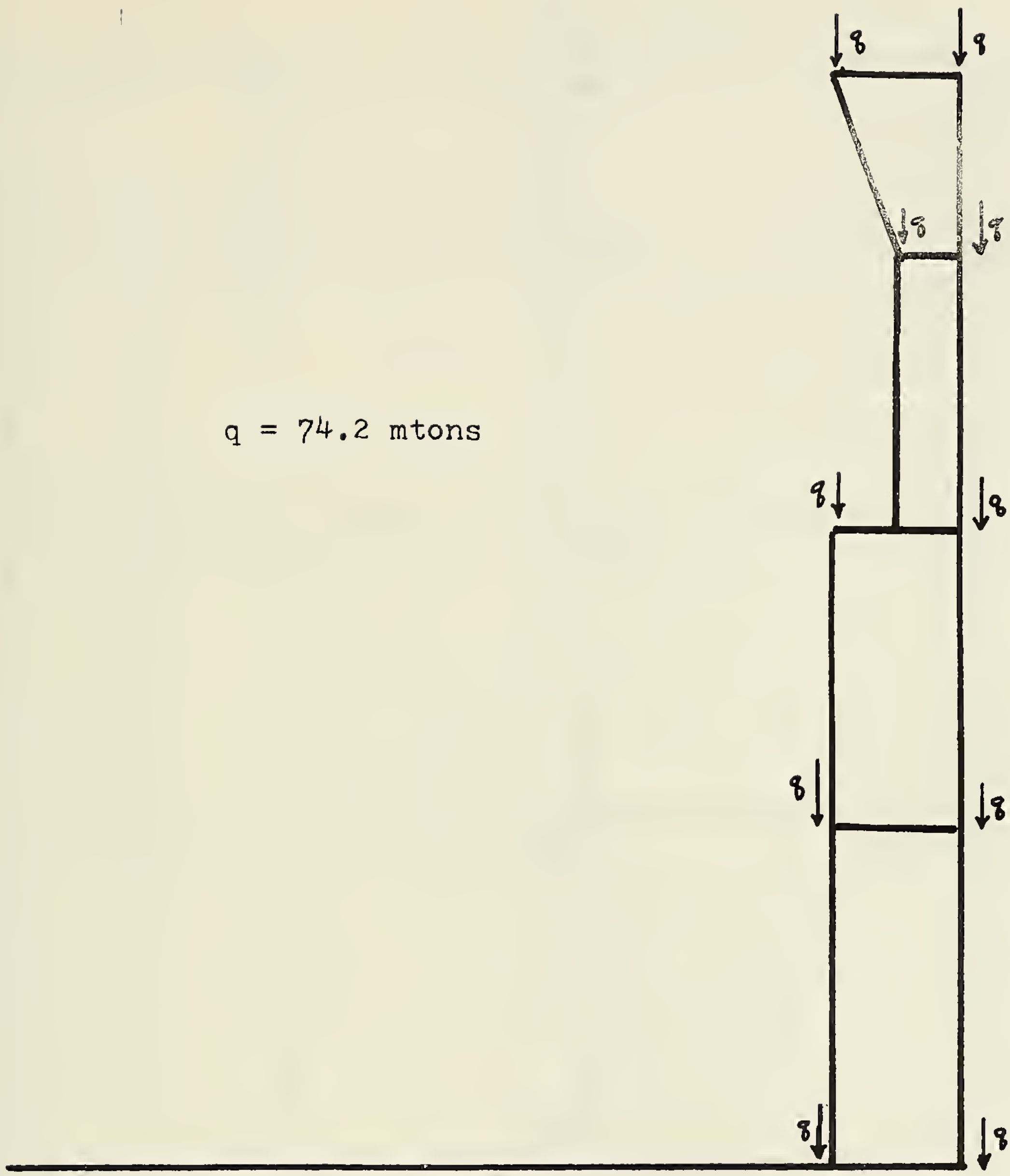
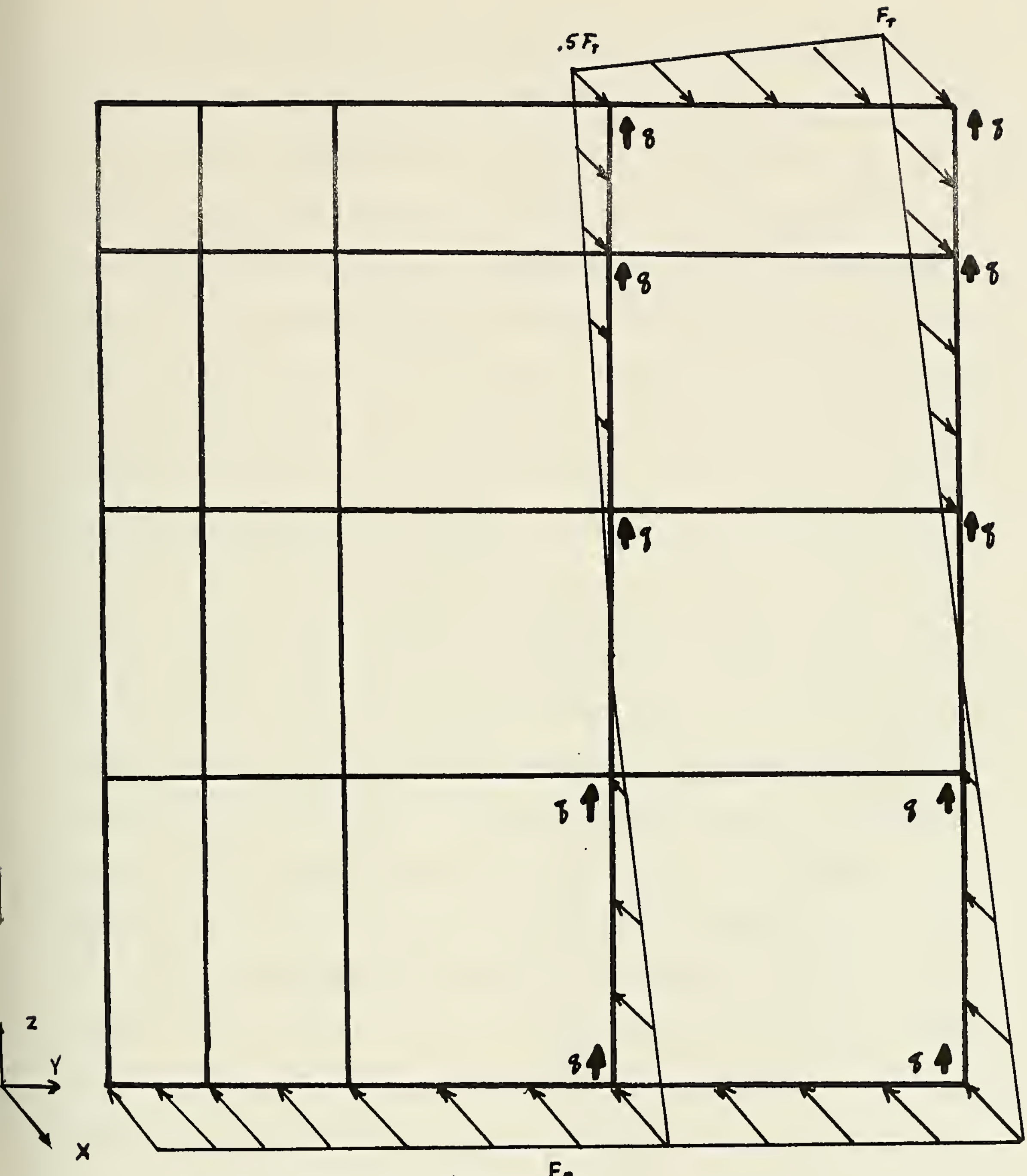


FIGURE 26

FRAME 228 BOUNDARY CONDITIONS

HOGGING CASE—RUN II



F_t = 6.929 mtons/cm
F_b = 4.156 mtons/cm
q = 61.05 mtons

FIGURE 27

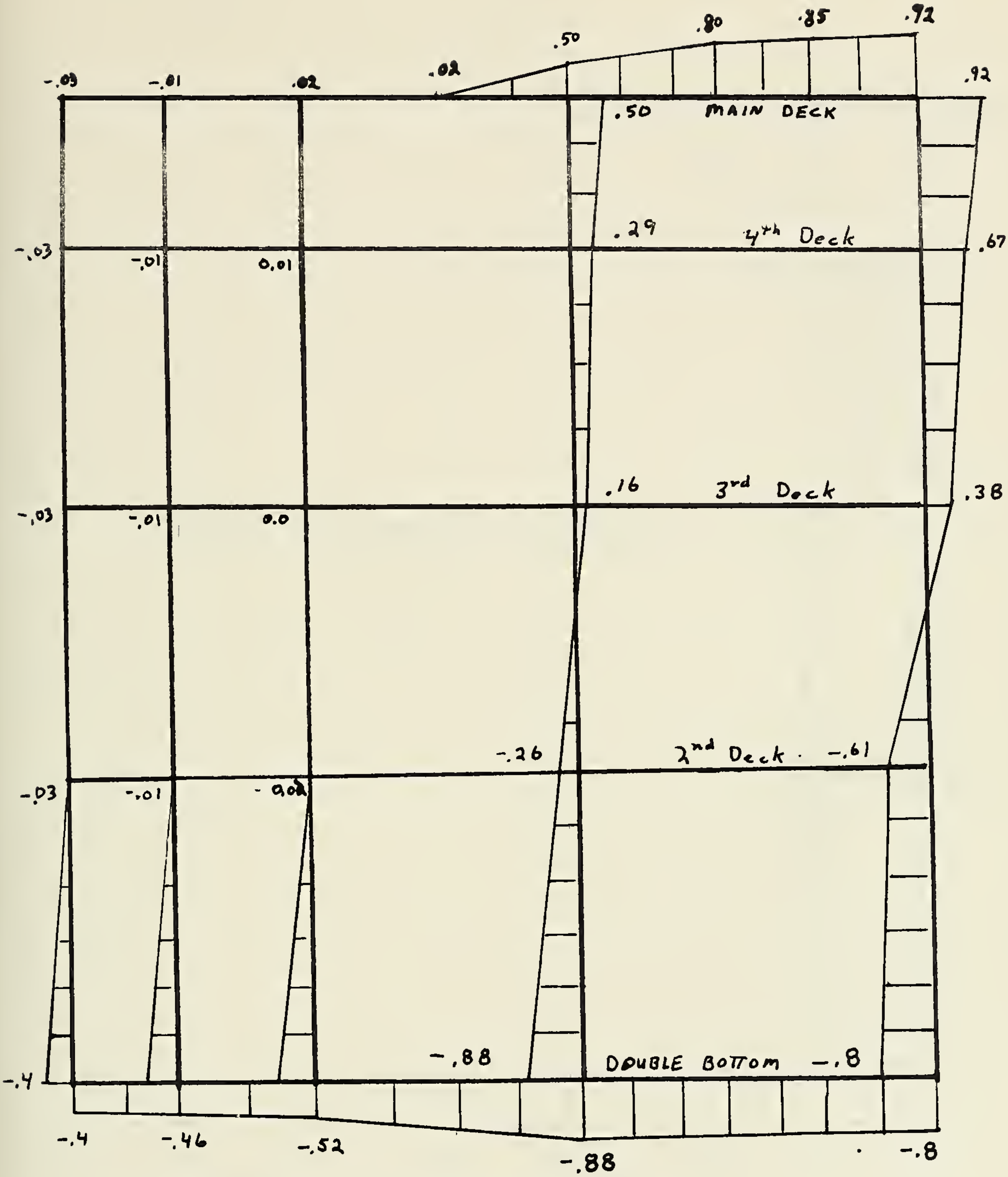
FRAME 195 BOUNDARY CONDITIONS

HOGGING CASE—RUN II

sonable than had those of the first run. The positive Z direction deflection of the double bottom near the origin had completely disappeared with the elimination of the rigid body motion that had been caused by the miscalculation of the longitudinal forces. However, as can be seen from Figure 28 the longitudinal stress distribution on the main deck at frame 195 still did not come close to the distribution obtained for the exact solution of the infinite plate with the circular hole. The results from Run II indicate that the stress at the inner web is approximately 54 per cent of the longitudinal stress at the edge of the main deck. This 54 per cent represented an improvement over the 88 per cent obtained in the first run but still falls short of the desired result of 19 per cent obtained from the infinite plate solution. It was obvious that the forces applied to the main deck that are part of the couple used to simulate the bending had to be redistributed again.

The problem on the fourth deck where the inner web joined the circular hold wall was greatly improved, however, the stress in some members was still excessive. The bending stresses remained the reason for this problem with members 427, 428, and 429 being pulled out of the circular shape by member 409. The poor distribution of the bending moment couple forces that was discussed in the previous paragraph would be one of the primary reasons.

As can be seen from Figure 29 the longitudinal stresses



Stresses are in units of mtons/cm^2

FIGURE 28

LONGITUDINAL STRESSES AT FRAME 195

HOGGING CONDITION—RUN II

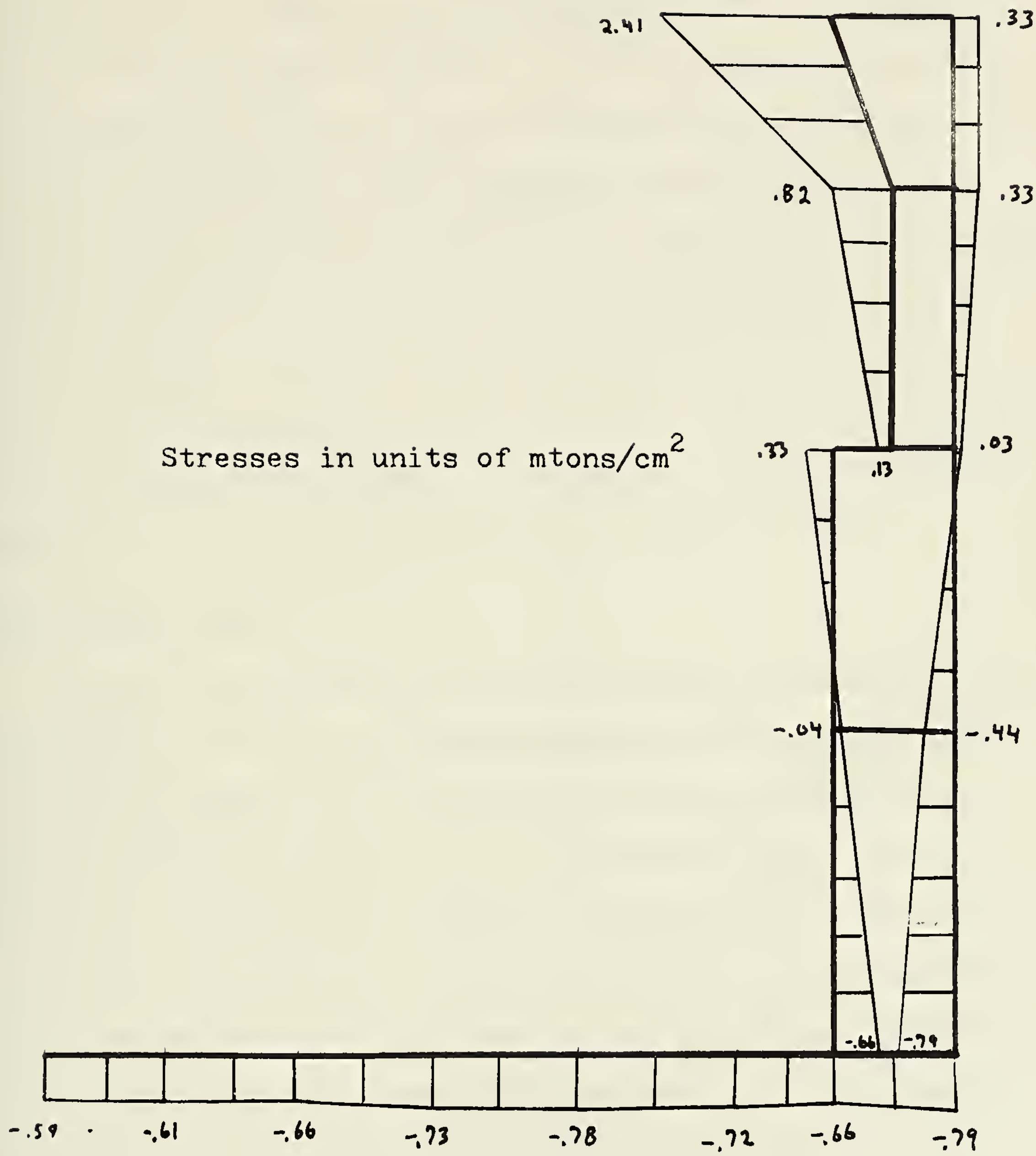


FIGURE 29

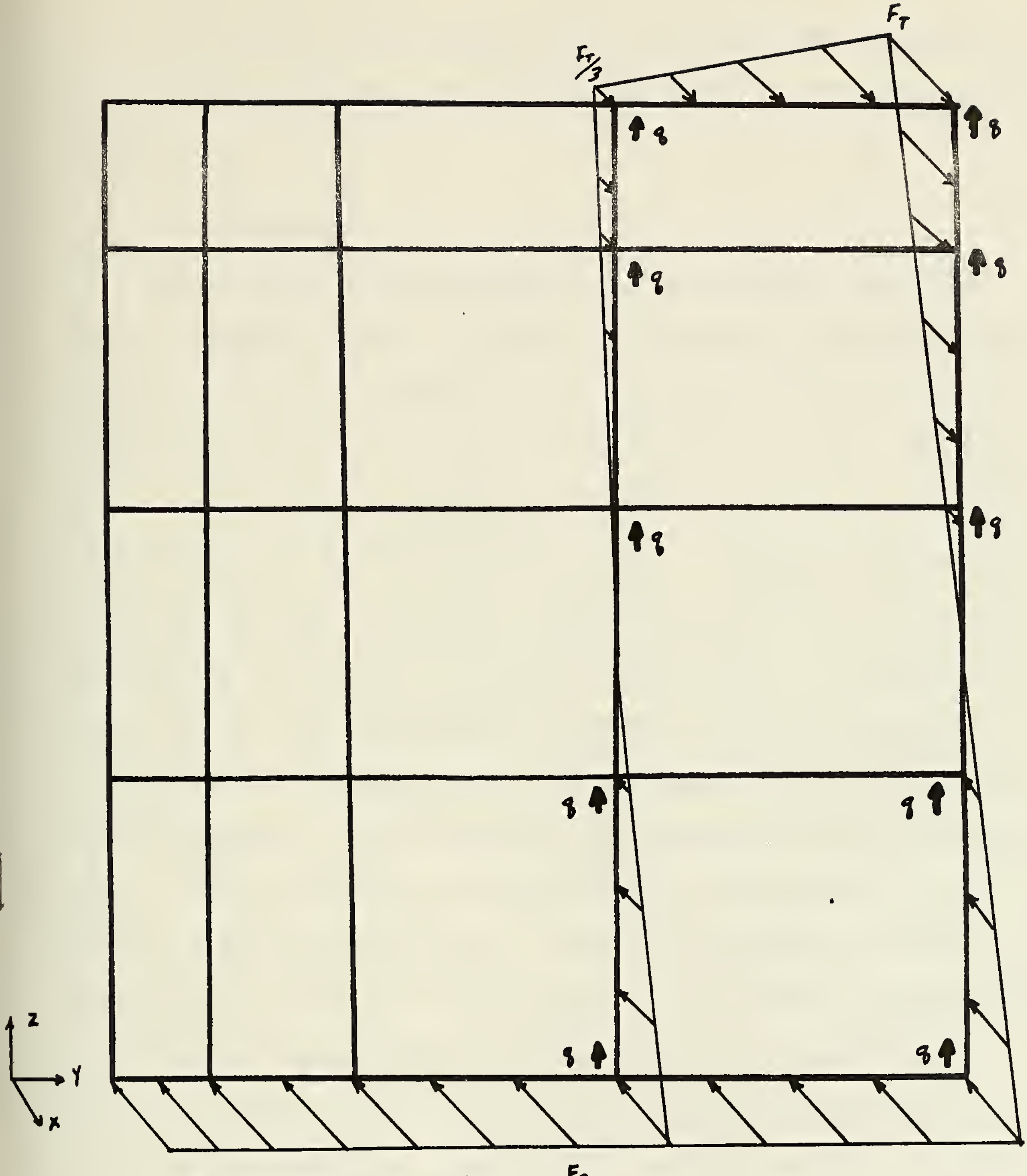
LONGITUDINAL STRESSES—FRAME 228

HOGGING CONDITION—RUN II

in this run still exceeded the yield stress in the main deck at frame 228. This problem was discussed at a conference with Technigaz representatives. At this conference it was discovered that there had been a communication problem concerning a revision to the blueprints from which this work was done. The revision concerned an additional longitudinal bulkhead under the main deck that had been added for structural purposes. Runs I and II were made using 20 millimeters as the thickness of the bulkhead. The correct thickness of this bulkhead was 45 millimeters. Thus it was necessary to make a third run to obtain valid results.

Third Run—Loads

Most of the loads for this run remained the same as for the second run, the only exception being the forces making up the upper half of the couple that was simulating the bending moment at frame 195. The distribution of these forces was changed such that the linearly varying force between the inner and outer web had a value at the inner web that was one third of the value at the deck edge. The vertical members in the inner and outer webs were also subjected to an X direction linearly varying load that had its maximum value at the main deck and had a value of zero at the neutral axis. The boundary conditions at frame 195 are shown graphically in Figure 30. The boundary conditions at frame 228 remain the same as shown in Figure 26.



F_t = 7.799 mtons/cm
F_b = 4.156 mtons/cm
q = 61.05 mtons

FIGURE 30

FRAME 195 BOUNDARY CONDITIONS

HOGGING CASE—RUN III

In addition, the properties of members 501 through 518 were recalculated to account for the error in the bulkhead thickness.

Third Run—Results

The results from the third run were better than the first or second runs. The shape of the longitudinal stress distribution in the main deck at frame 195 (Fig. 31) conformed more closely to that of the infinite plate solution. The value of the longitudinal stress at the inner web was 45 per cent of that at the deck edge. Although this is not the value obtained from the infinite plate model, time considerations as well as the high cost of each run indicated that further experimentation with the boundary conditions simulating the bending moment on the upper half of the ship was unwarranted. This decision was based on two considerations. The first was the uncertainty of the actual longitudinal stress distribution - the infinite plate had many drawbacks as was previously cited. The second consideration was that the distribution of the forces on the main deck would have very little effect on the vertical deflections of the support platform - the primary desired result. Figures 33 through 37 show the deflections obtained for the third run.

The maximum vertical deflection of any point in relation to any other point on the circular platform for the

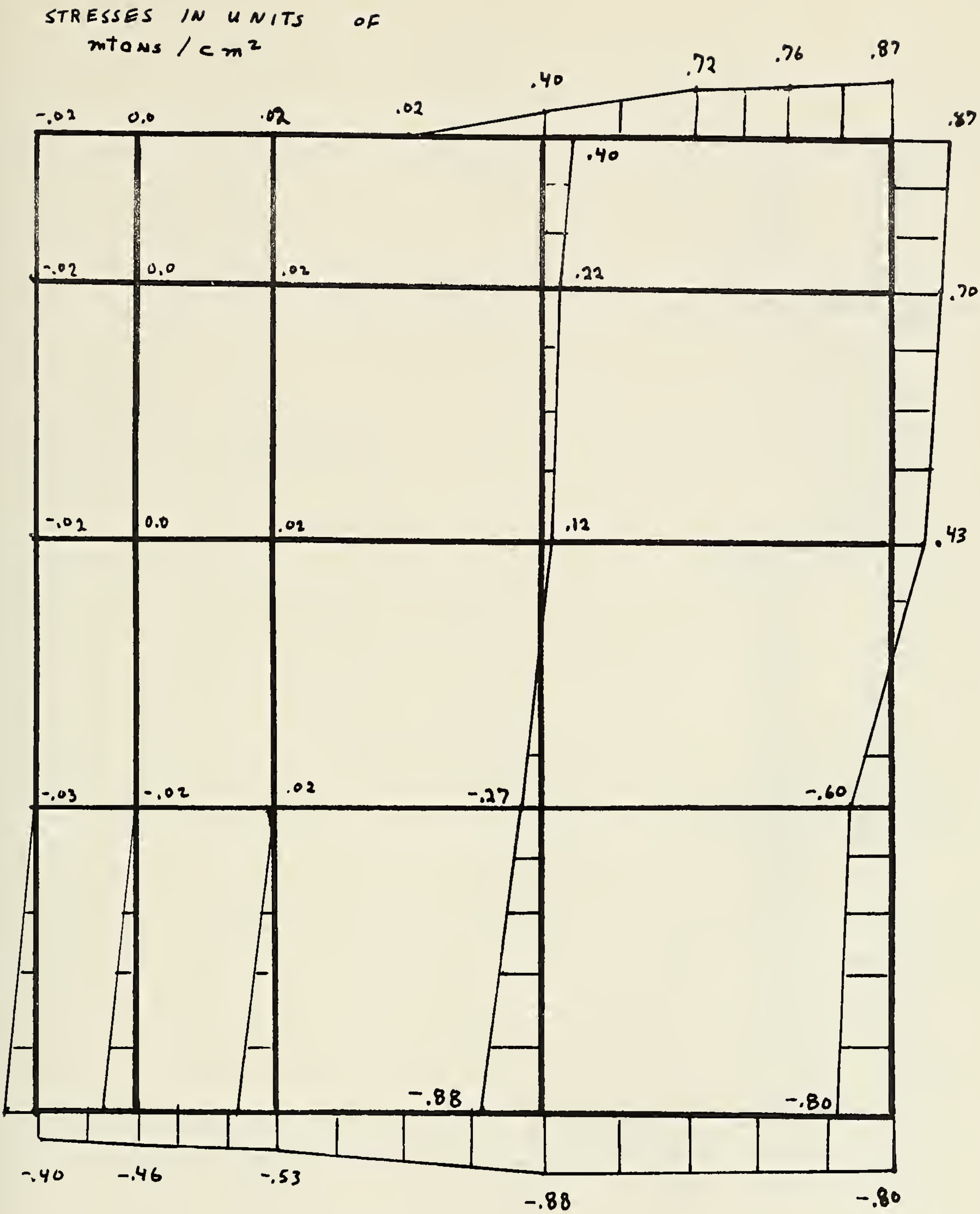


FIGURE 31

LONGITUDINAL STRESSES—FRAME 195

HOGGING CONDITION—RUN III

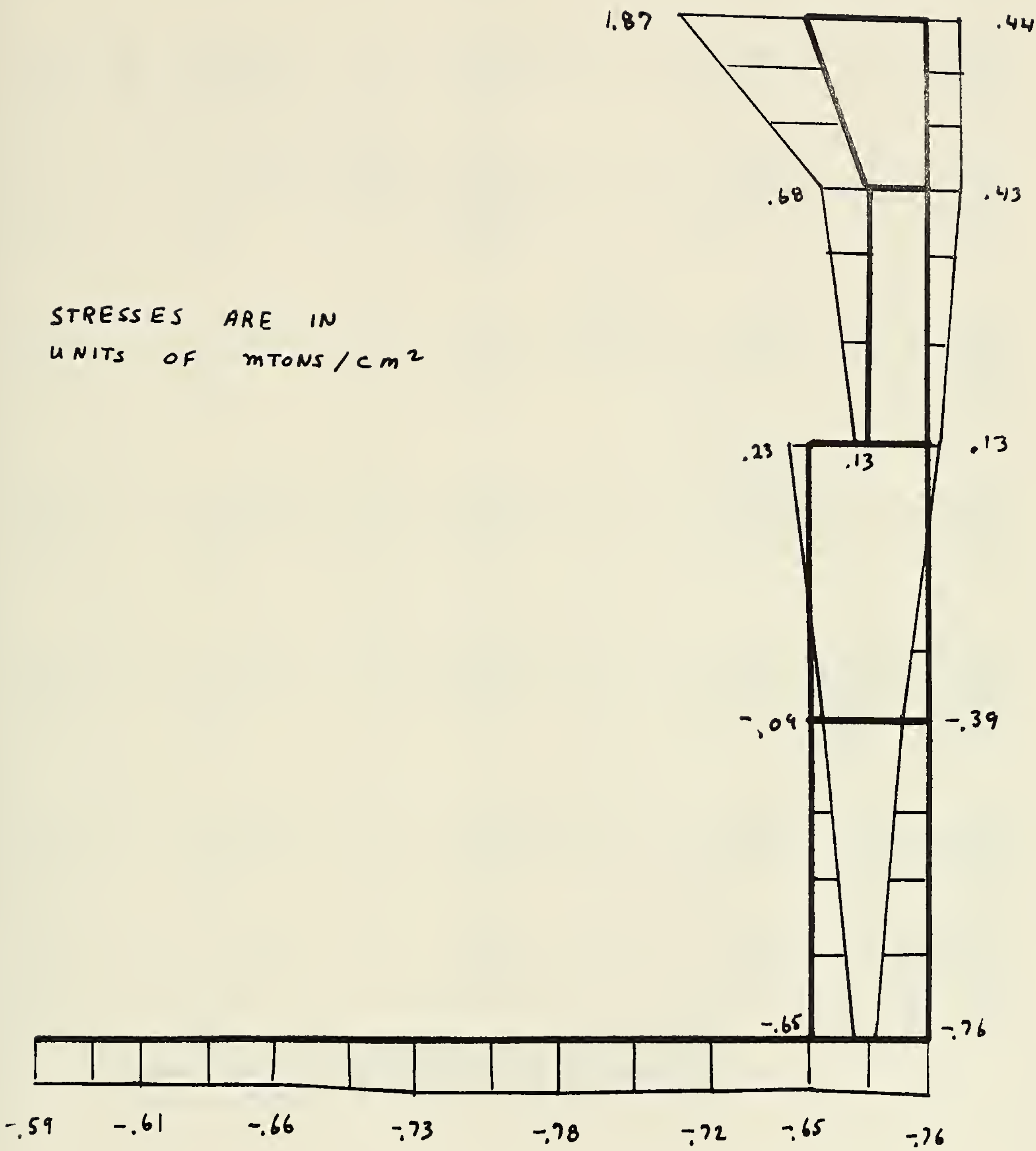


FIGURE 32

LONGITUDINAL STRESSES—FRAME 228

HOGGING CONDITION—RUN III

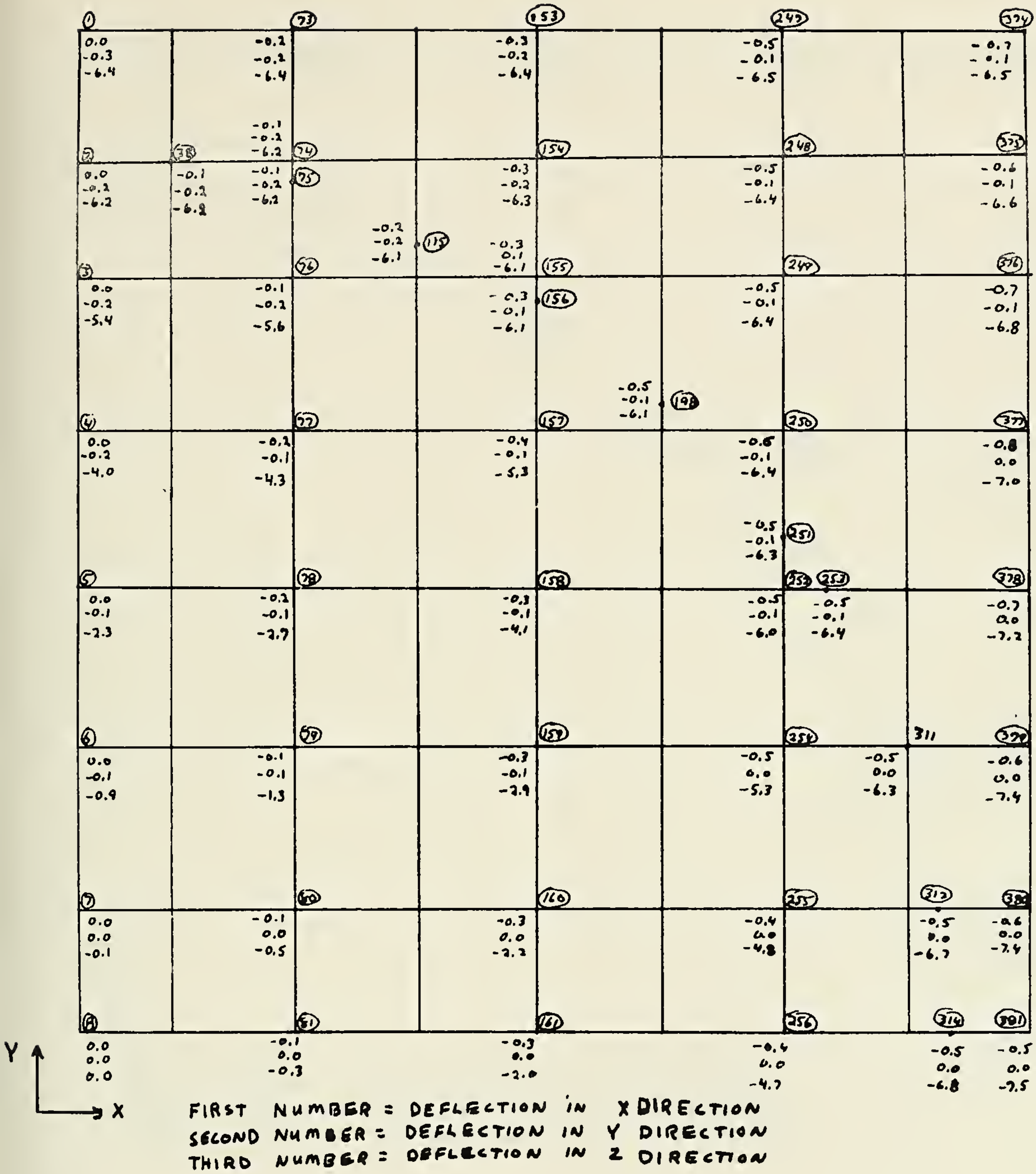
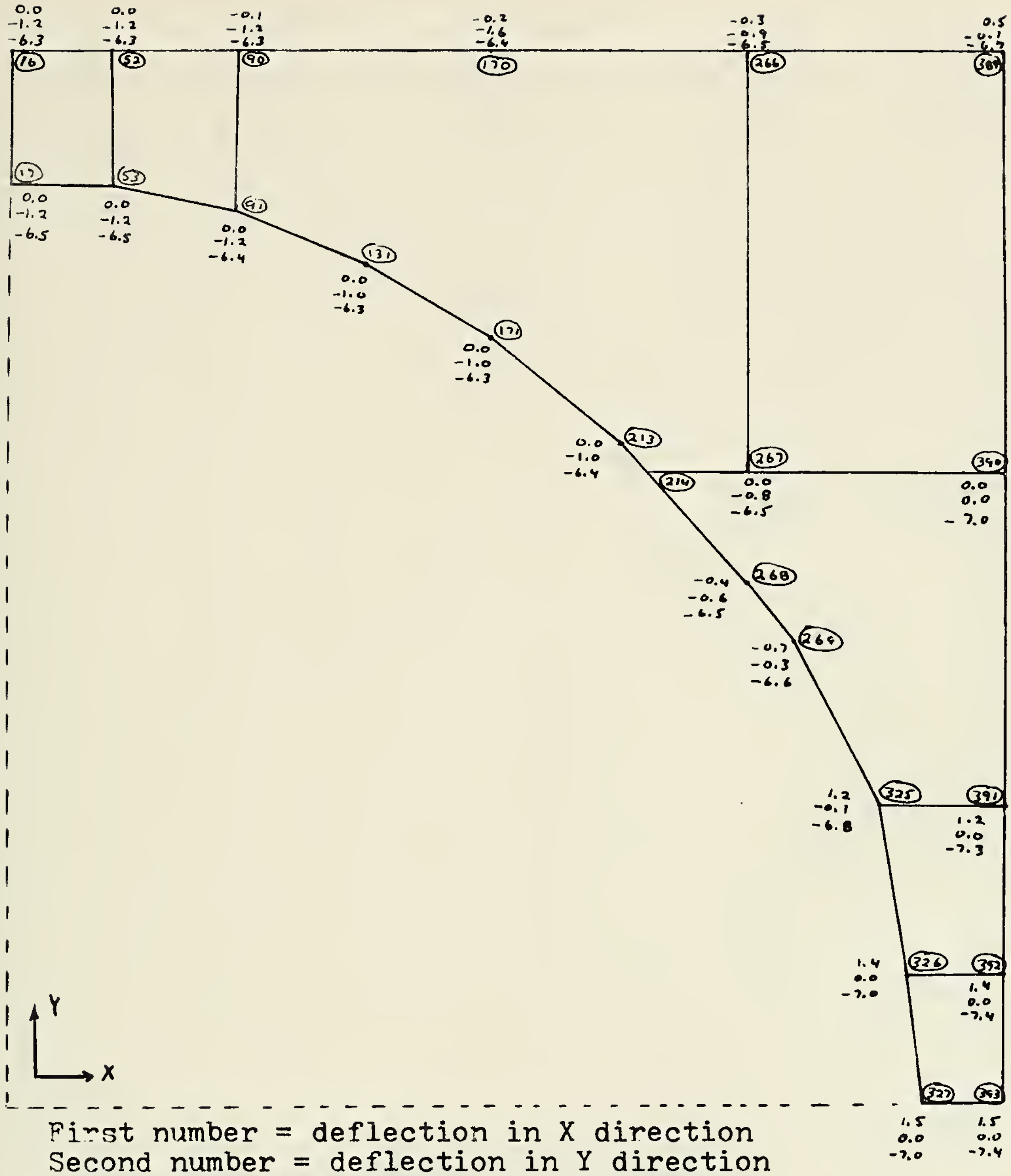


FIGURE 33

BOTTOM DECK DEFLECTIONS

HOGGING CONDITION—RUN III

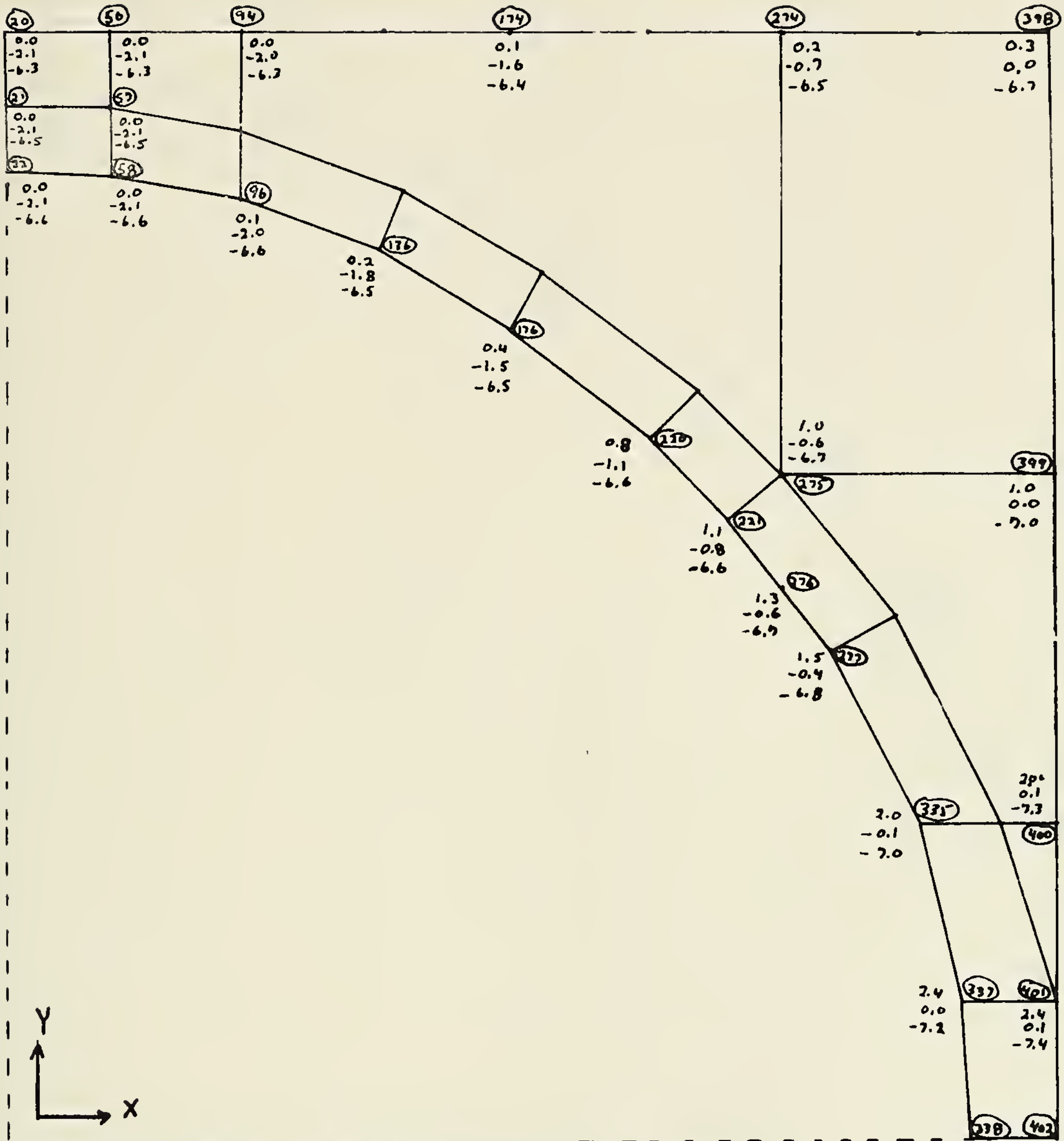


First number = deflection in X direction
Second number = deflection in Y direction
Third number = deflection in Z direction

FIGURE 34

SECOND DECK DEFLECTIONS

HOGGING CASE—RUN III

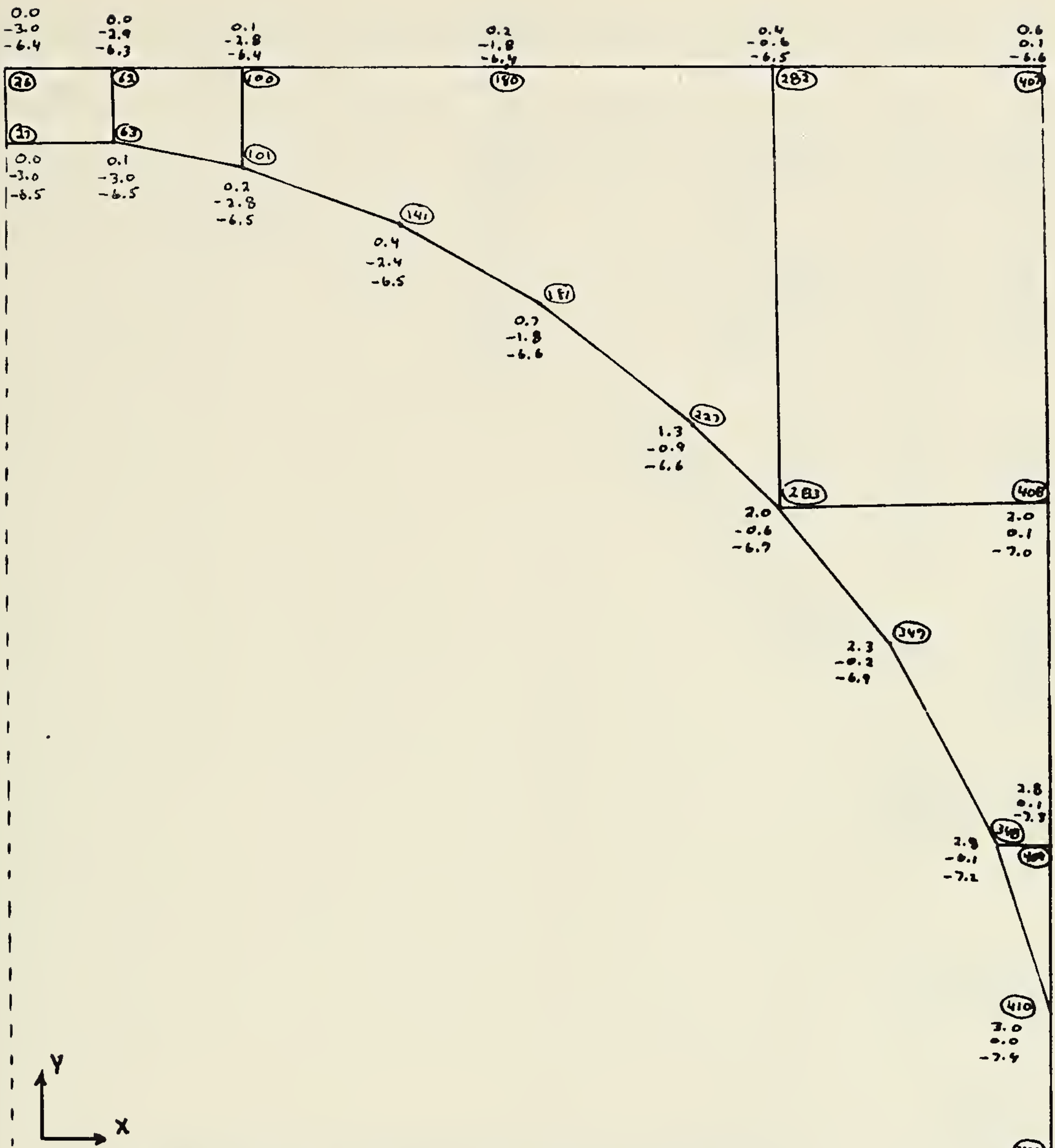


First number = deflection in X direction
Second number = deflection in Y direction
Third number = deflection in Z direction

FIGURE 35

THIRD DECK DEFLECTIONS

HOGGING CASE—RUN III

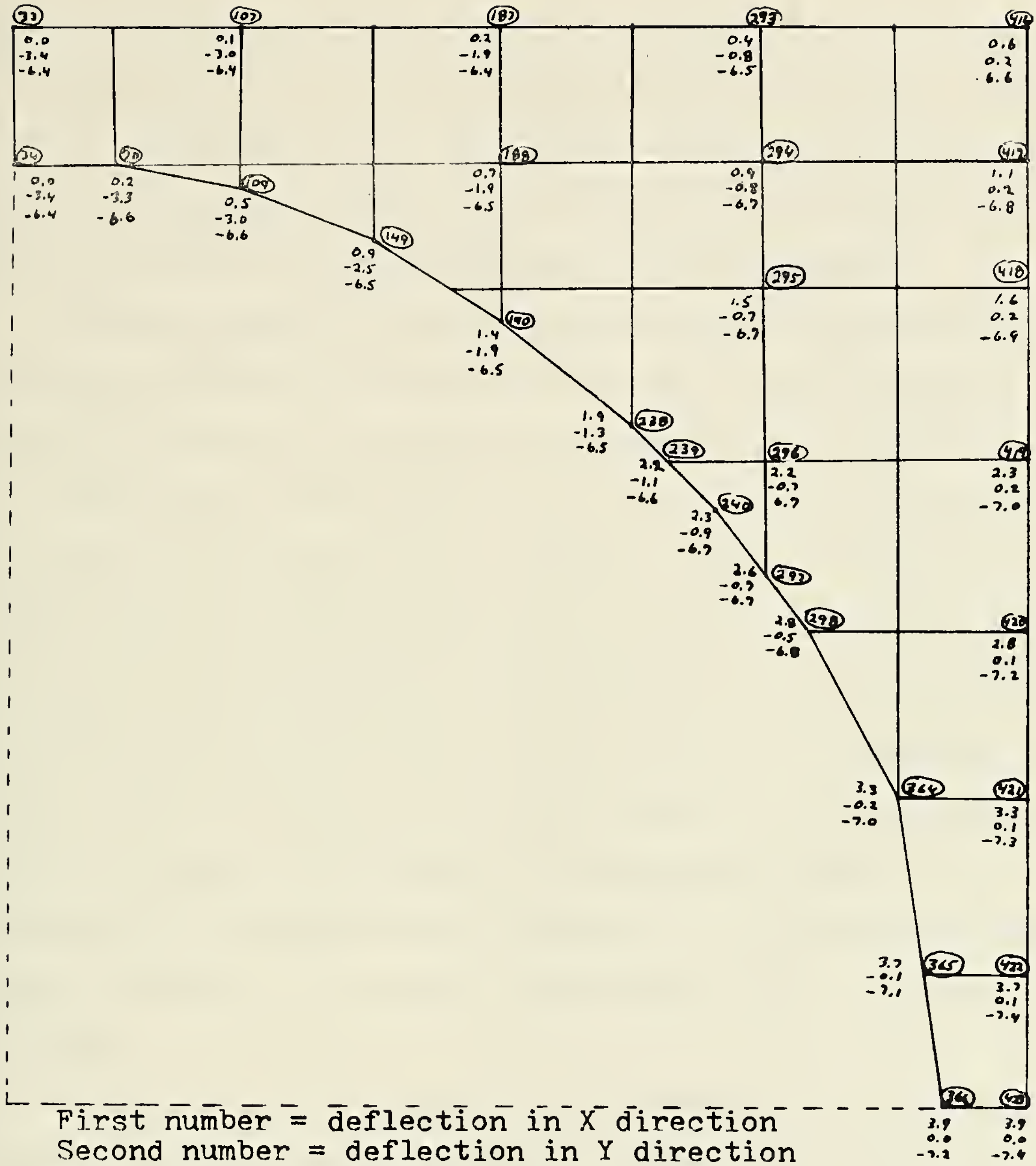


First number = deflection in X direction
Second number = deflection in Y direction
Third number = deflection in Z direction

FIGURE 36

FOURTH DECK DEFLECTIONS

HOGGING CONDITION—RUN III



First number = deflection in X direction
Second number = deflection in Y direction
Third number = deflection in Z direction

FIGURE 37

MAIN DECK DEFLECTIONS

HOGGING CONDITION—RUN III

first, second, and third runs were 1.0 cm, 0.9 cm, and 0.6 cm, respectively. Even with major changes in boundary conditions (between run I and run II) and changes in the longitudinal strength of the main deck (between run II and run III) this deflection difference remained fairly constant.

Further support for the argument that the distribution of forces would have little effect on the vertical deflections can be seen by looking at the magnitude of the vertical deflections between runs II and III in which the vertical loads were constant. The smallest vertical deflection on the support platform occurred at joint 22 and was -6.5 cm and -6.6 for runs I and II respectively, while the largest occurred at joint 338 and was -7.4 cm and -7.2 cm respectively. The conclusions being that changes in the distribution of forces simulating the bending moment and even changes in the longitudinal strength of the main deck have little effect on the vertical deflections of the support platform.

The same is, naturally, not true for the transverse or longitudinal deflections since the boundary conditions will greatly affect the longitudinal elongation and subsequent transverse contraction of the circular support platform when the ship is in a hogging situation. The maximum deflection in the X direction of the support joints occurred in the longitudinal direction and was due to the elongation of the circular support platform. This joint deflection was 4.4

cm, 3.3 cm, and 2.5 cm for the first, second, and third runs respectively.

The largest Y direction deflection occurred at the transverse centerline of the tank. This contraction of the circular platform in the transverse direction was directly linked to the elongation in the longitudinal direction. The maximum magnitude of this transverse deflection was 4.1 cm, 2.8 cm, and 2.1 cm for the three runs.

The third run had the most realsitic longitudinal distribution. Thus, the maximum expected deflection of any joint normal to the circular shape for this loading condition was 2.5 cm. It was felt that this number was conservative and could be used for further work on the preliminary design.

The areas of high stresses that occurred in the third run were in basically the same areas as in the two preceeding runs, although the magnitude of the stresses were lower. The maximum longitudinal stress occurred at the narrow portion of the main deck as would be expected. The longitudinal stresses when combined with the bending stresses resulted in a total member stress that was greater than yield for the beams in this area.

Vertical members in this same area near the narrow portion of the circular hold between the lower two decks had combined stresses that exceeded the yield stress. The primary cause of this was the bending stresses which result-

ed from a combination of loads involving the transverse contraction of the circular hold area and the loads due to the water pressure acting on the side of the hull. In addition vertical members of the circular support platform at the ship's longitudinal centerline indicated high bending stresses due to the longitudinal elongation of the circular support platform. The same elongation produces high bending stresses in members 427 and 428.

It was felt that the fact that beam elements were being used to model plates in the outer skin of the ship was the cause of the high bending stresses in this region. The linear force distribution simulating the water pressure caused the members to bow in, resulting in high stresses. However, in the actual case there would be another point of support in the middle of the beam, cutting the amount of bowing as was previously explained in the mathematical model chapter.

However, it was the opinion of the writer that steps should be taken to insure that the bending stresses due to the elongation and contraction of the circular hold are substantially smaller than the results indicated for this model. The same is true for the normal stresses in the main deck at the narrow portion of the hull near the transverse centerline of the tank.

The increase in the area of members 501 and 510 should have brought about a proportional decrease in the longitudi-

nal stress level of the main deck at frame 228. This stress reduction could not be checked directly for each member because the distribution of boundary forces in the main deck at frame 195 had been changed between run II and run III. However, the axial force on each member was one of the outputs of this program. These forces were used as correction factors to obtain the stress level of the members if the same distribution had been used for run II as was used for run III.

This was accomplished by using:

$$F = \sigma A$$

and $\quad F_2 = \sigma_2 A_2 \qquad\qquad F_3 = \sigma_2^* A_2$

since $\quad A_2 = A_2$

$$F_2/\sigma_2 = F_3/\sigma_2^*$$

$$\sigma_2^* = \sigma_2\ (F_3/F_2)$$

where σ_2 = actual longitudinal stress obtained for run II

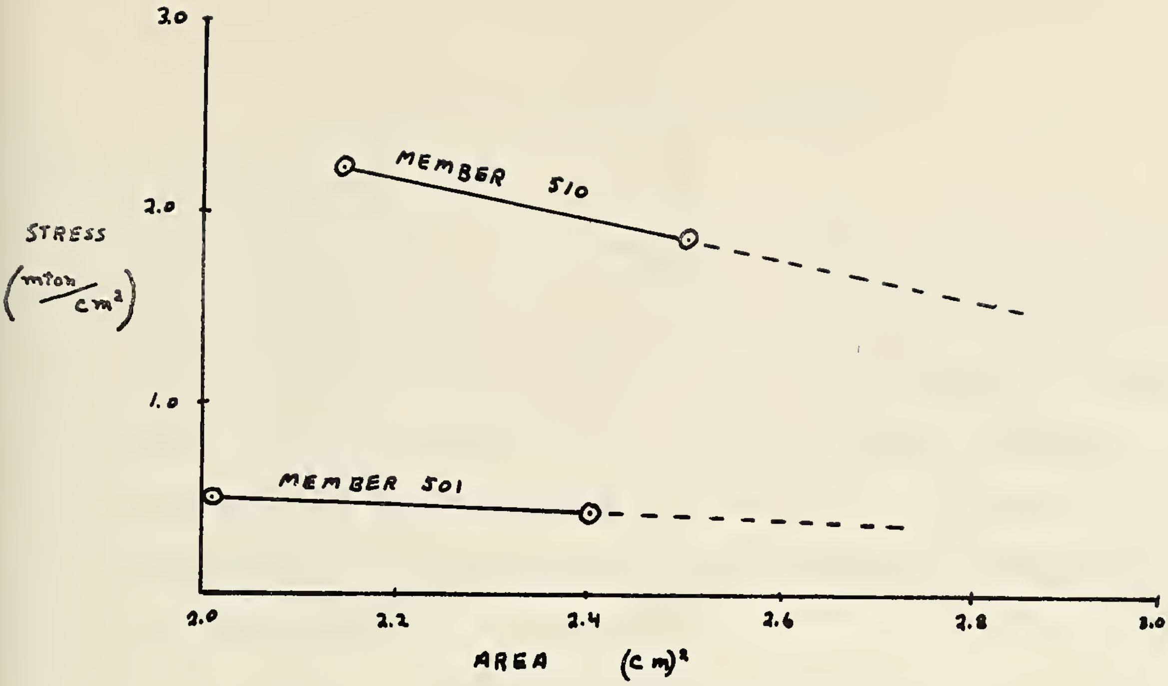
σ_2^* = longitudinal stress that would have been obtained for run II if the boundary conditions of run III had been used

F_2 = axial force in member for run III

F_3 = axial force in member for run III

A_2 = cross sectional area of member for run II

Since the stresses and area can be considered inversely proportional if a constant force is applied, the graph of the stress versus area of a member would be approximately linear. Thus, the information from runs II and III can be used to determine the area required for any desired stress level when the vessel is in the hogging condition. See Figure 38.



	MEMBER 501	MEMBER 510
A_2	0.2014 m^2	0.2128 m^2
σ_2	0.33 mtons/cm^2	2.41 mtons/cm^2
F_2	671.0 mtons	5128.0 mtons
σ_2^*	0.518 mtons/cm^2	2.212 mtons/cm^2
A_3	0.2396 m^2	0.2504 m^2
σ_3	0.44 mtons/cm^2	1.87 mtons/cm^2
F_3	1053.0 mtons	4706.0 mtons

FIGURE 38

RELATIONSHIP OF AREA AND STRESS LEVEL

IN MEMBERS 501 AND 510 FOR HOGGING CASE

THE ANALYSIS—SAGGING CONDITION

General Discussion

The last case to be investigated was with the ship in an upright position, fully loaded with the wave crests at the end of the ship and the wave hollow at amidships. Again the wave height was taken to be 0.03 of the wave length or 8.4 meters. The draft at frame 228 was then calculated by subtracting the wave height from the stillwater draft, this resulted in a draft of 6.80 meters.

The shear and moment curve for this loading condition were also porvided by Technigaz. The bending moment at frame 195 was -309,800 meter-tons while the shear load was 296 mtons as indicated by Figure 39. Since the dynamic loads would be slightly less than the static loads for the sagging condition, the static loads were used to give conservative results.

First Run—Loads

Again the beam model was subjected to boundary loads, loads due to water acting on the hull, cargo loads and loads due to the steel weight. The static steel weight of 7.78 mtons/joint was applied to each joint of the model.

The cargo load was 14,428 metric tons or 3,607 metric tons per quarter tank section. The load was equally distributed among the joints resulting in a load of 360.7 metric tons at all the joints except joints 22 and 338 which were

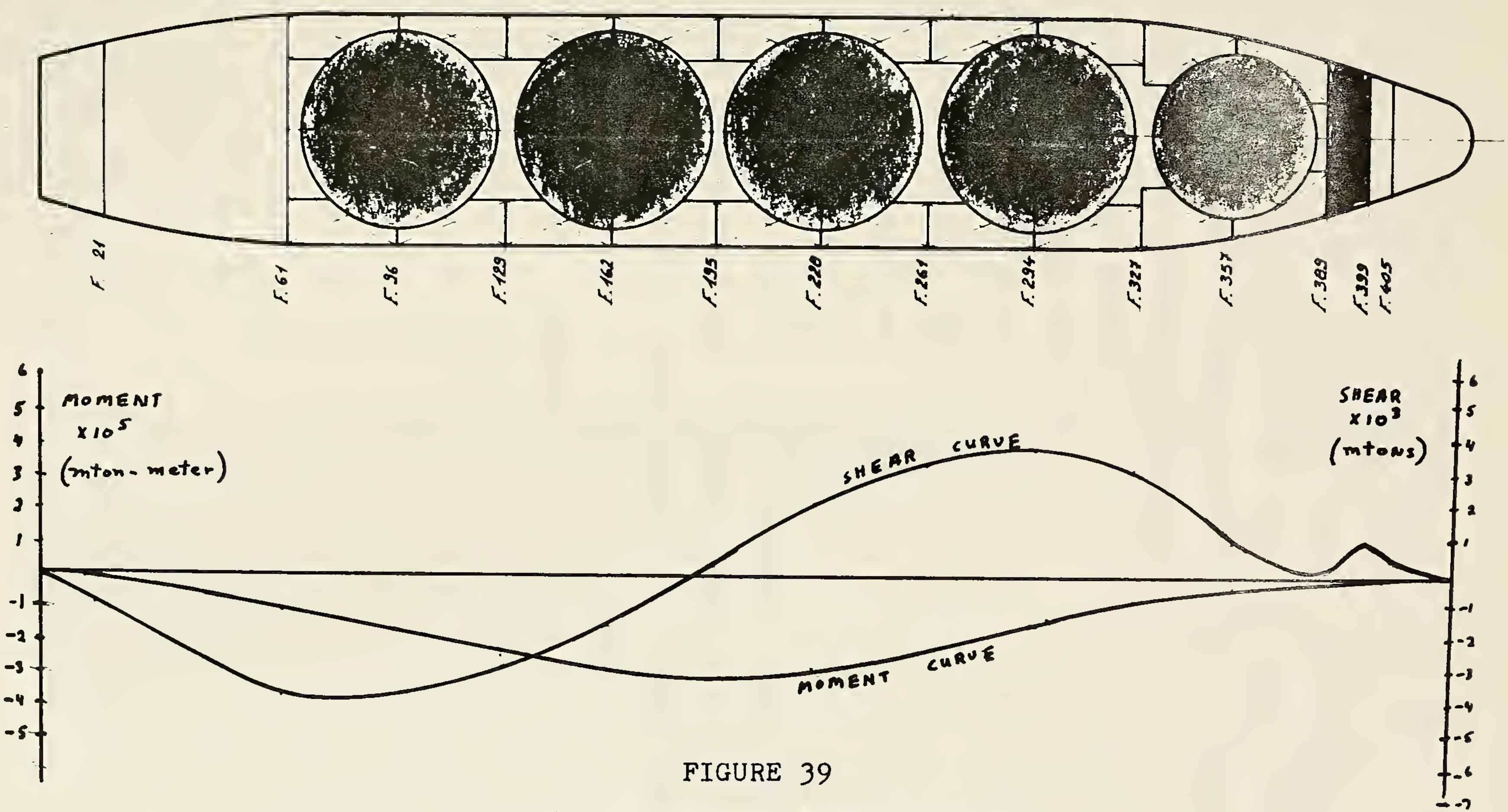


FIGURE 39

SHEAR AND BENDING MOMENT CURVES

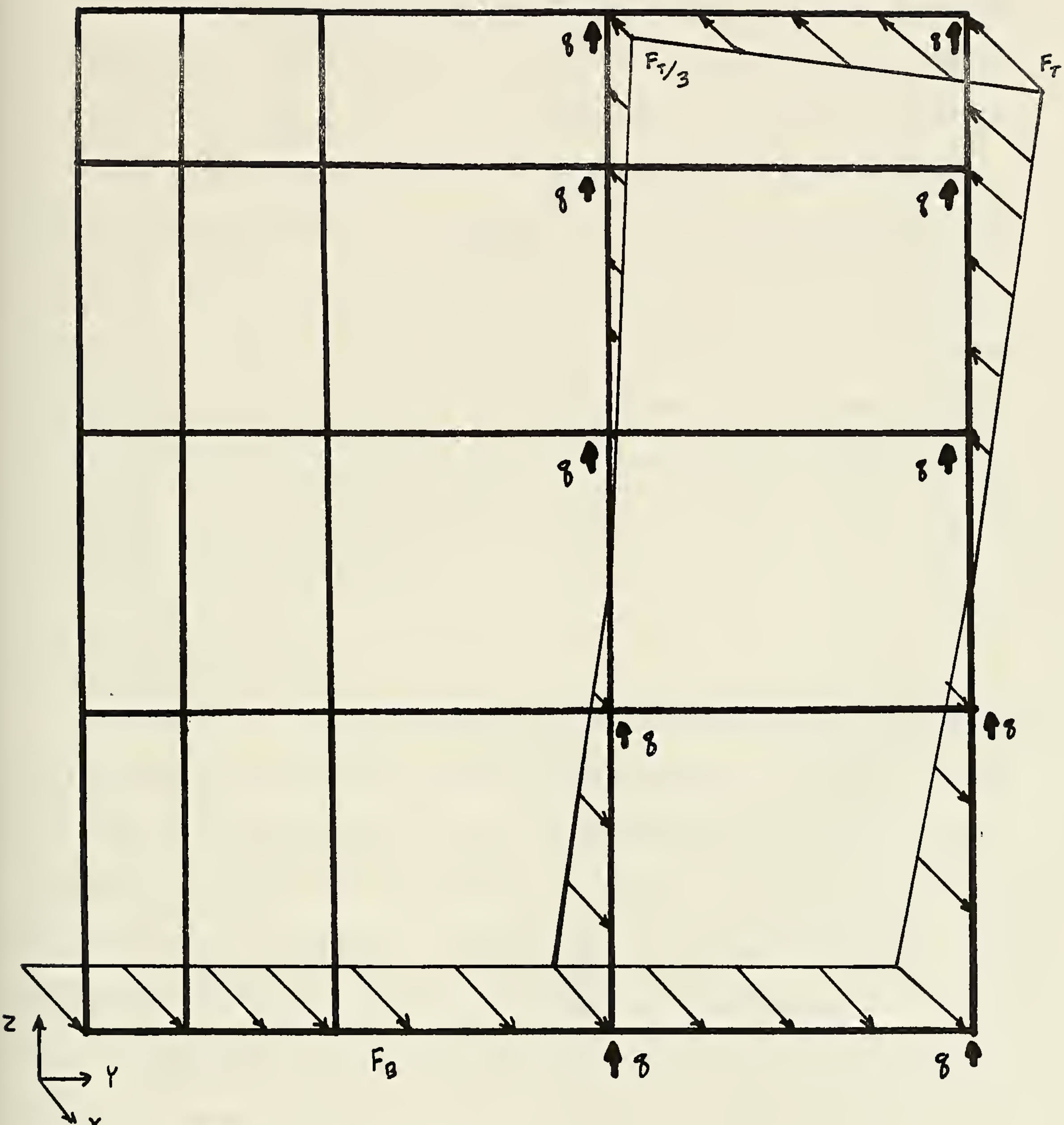
FULLY LOADED—SAGGING CONDITION

in the planes of symmetry and had one half the applied load of the outer joints or 180.4 metric tons.

The forces due to the water acting on the bottom and side hull were calculated as if the depth of water remained constant over the entire quarter tank section. The forces on the side of the ship were idealized as linearly varying loads on the vertical members. As in the hogging case the bottom forces were applied to the model as uniform forces— half of the total forces to the longitudinal members and half to the transverse. See Sample Calculation 3.

The bending moment was simulated by coupled forces taking the neutral axis to be 10.5 meters from the double bottom. The bending moment of 309,800 meter-mtons was distributed as it was for Run III of the hogging case. Above the neutral axis a linear load was applied in the negative to the transverse member of the main deck between the inner and outer frames. The magnitude of the force at the inner web was one third of the force at the deck edge. A linear load was also applied to the inner and outer bulkheads from the main deck to the neutral axis. The other half of the couple was applied below the neutral axis in the positive X direction. A uniform load was imposed across the entire half width of the double bottom, with a linearly decreasing load on the webs, starting at the double bottom up to the neutral axis. See Figure 40 for a graphical representation.

The shear load of 296 mtons for the whole cross section



F_t = 4.983 mtons/cm
F_b = 2.655 mtons/cm
q = 14.7 mtons

FIGURE 40

FRAME 195 BOUNDARY LOADS

SAGGING CASE—RUN I

or 148 mtons for the quarter tank model was equally distributed as a joint load of 14.8 mtons acting in the positive Z direction on each of the ten joints that lie in the intersection of frame 195 and the inner and outer web bulkheads. The one remaining boundary condition, the shear at frame 228, was determined by summing the vertical forces applied to the model and then changing the sign of this summation thus causing the model to be in equilibrium in the vertical direction. This shear at frame 228 was determined to be 1598 mtons. This resulted in a joint load of 159.8 mtons for each of the joints in the inner and outer web bulkheads of frame 228 (Fig. 41).

First Run—Results

Generally, the deflections and stresses for the sagging case were less than for the hogging case. As would be expected the directions of the longitudinal and transverse deflections were the opposite of those in the hogging case. The circular tank hold contracted in the longitudinal direction and elongated in the transverse direction.

The shape of the longitudinal stress distribution in the main deck conformed almost exactly to the distribution obtained in the third run of the hogging case although the sign was different because the deck was in compression for this case (Fig. 42). The longitudinal stress at the inner web was 44 per cent of the stress at the deck edge. This

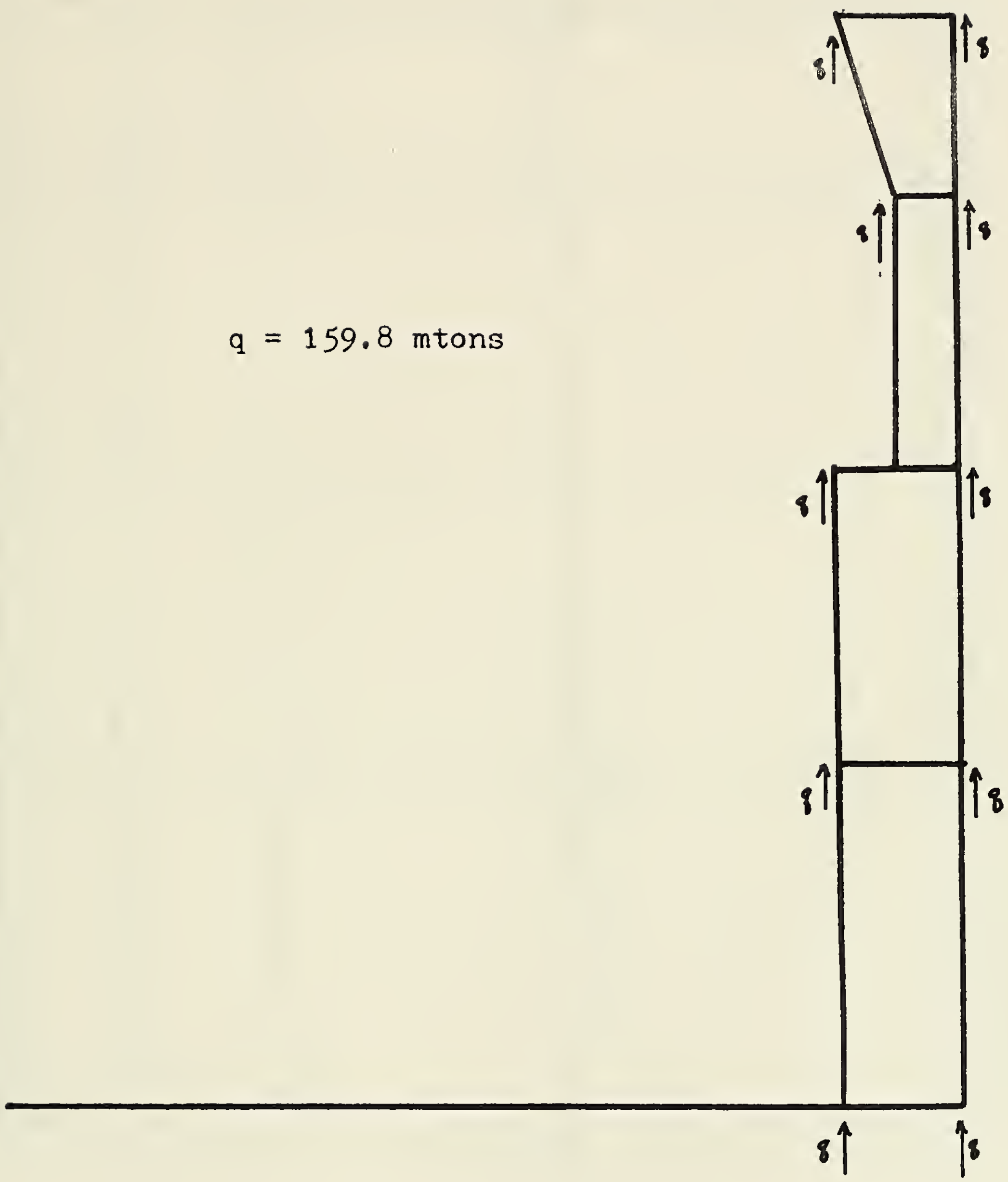
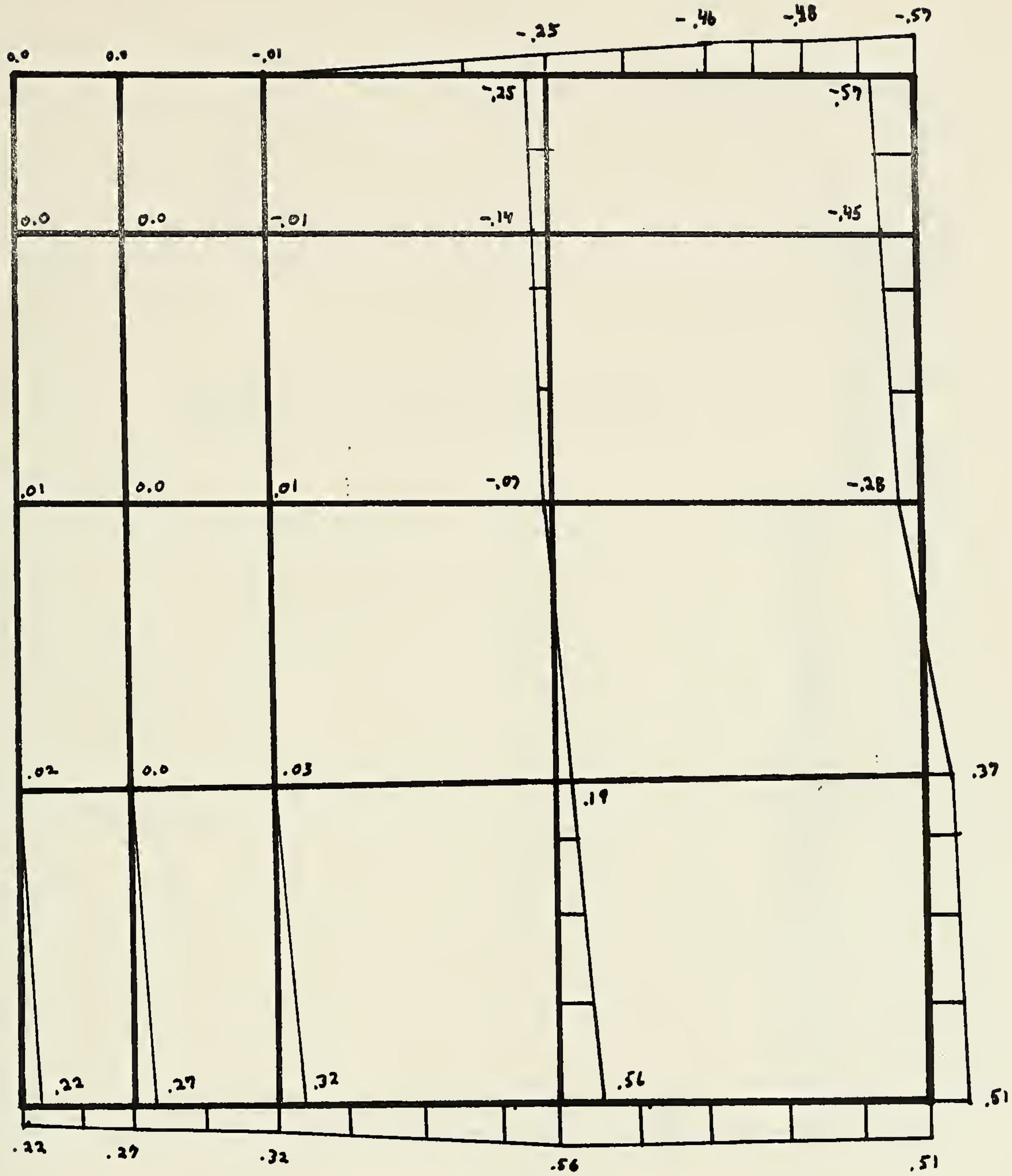


FIGURE 41

FRAME 228 BOUNDARY LOADS

SAGGING CASE—RUN I



Stresses in units of mton/cm^2

FIGURE 42

LONGITUDINAL STRESSES—FRAME 195

SAGGING CASE—RUN I

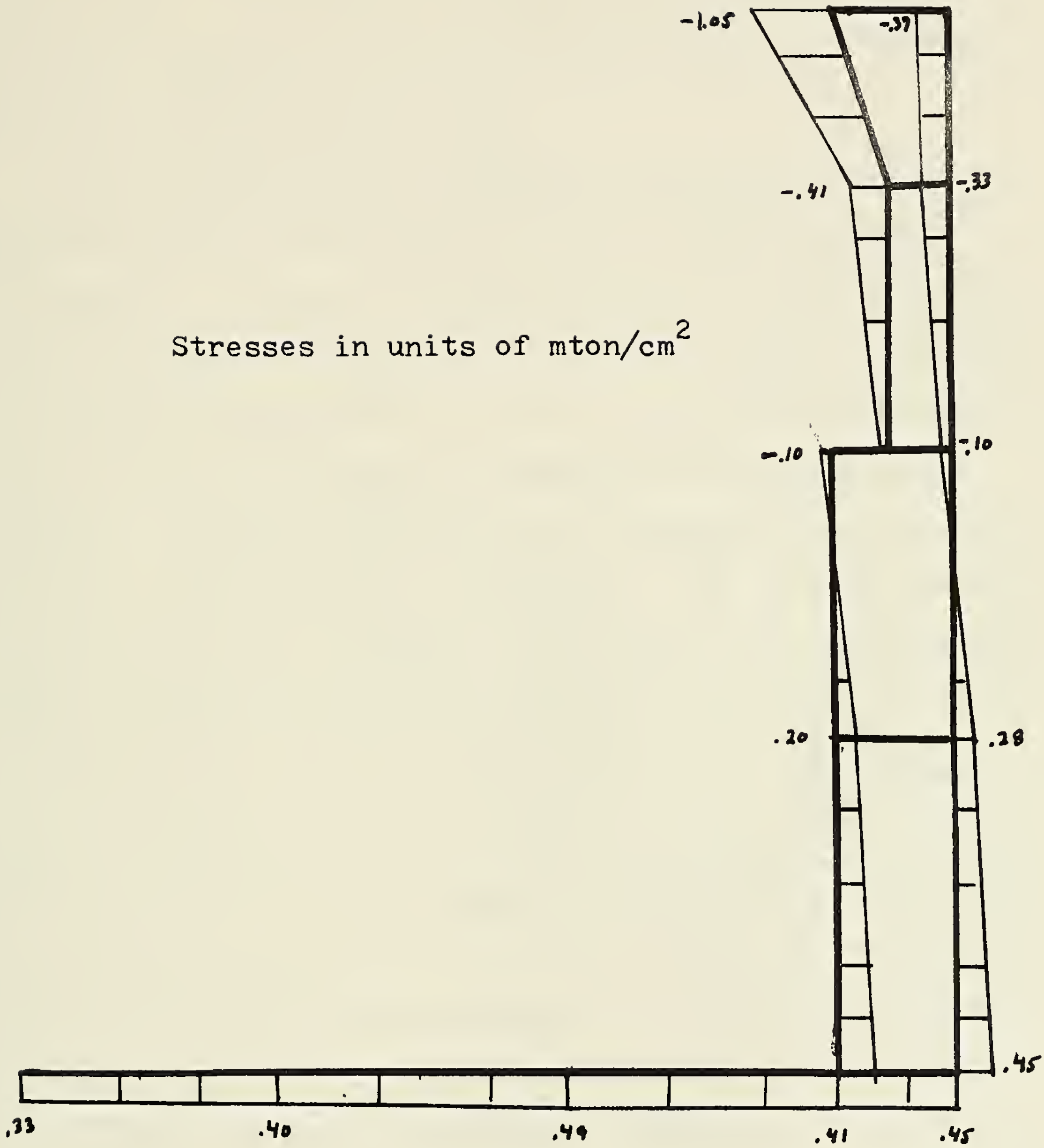


FIGURE 43

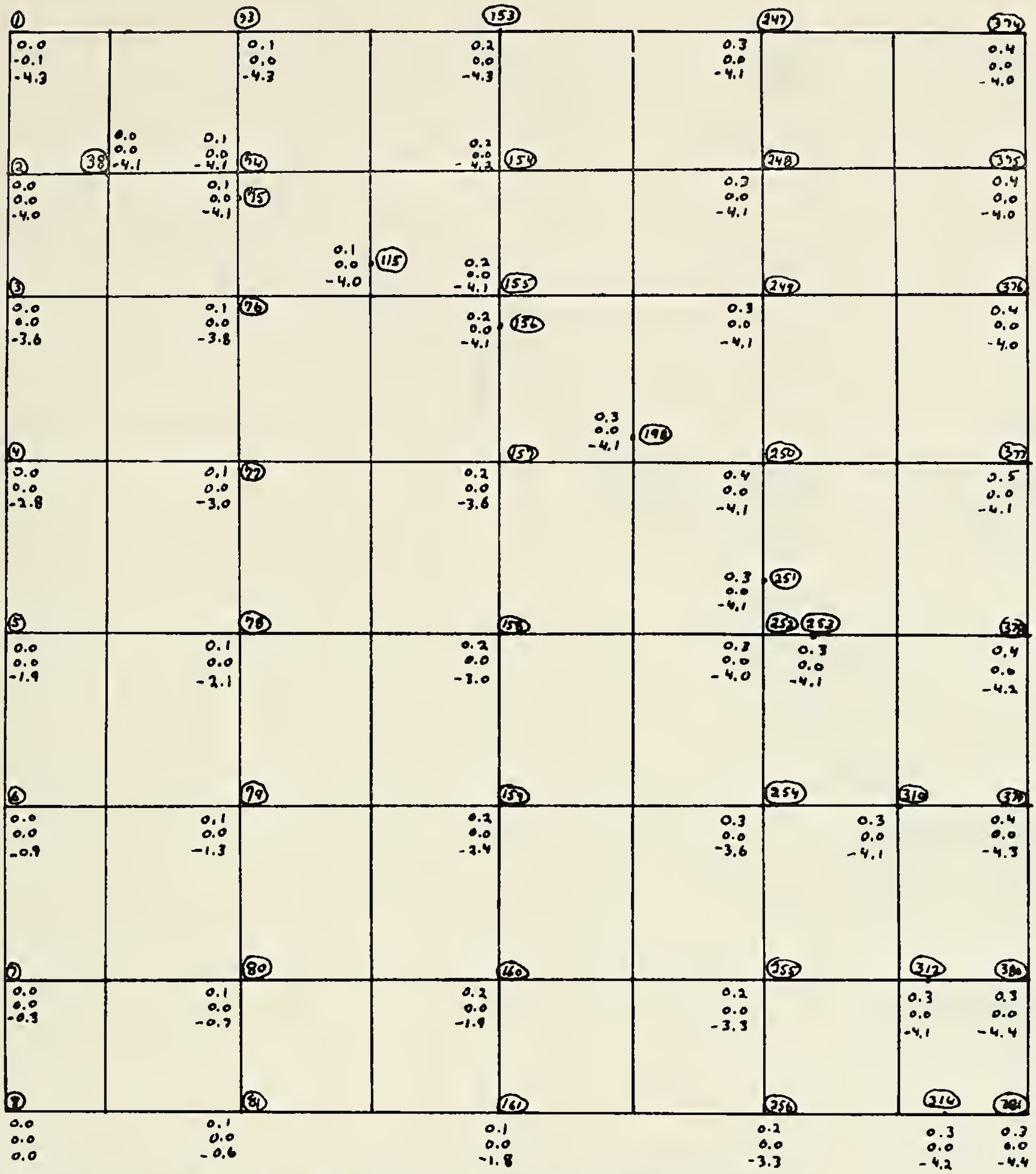
LONGITUDINAL STRESSES—FRAME 228

SAGGING CASE—RUN I

result is very close to the 45 per cent obtained for the hogging case. If the main deck had been an infinite plate subjected to pure compression or tension the distributions would have been exactly the same.

The deflections in the sagging case were of a smaller magnitude than the other runs as can be seen from Figures 44 through 48. Figure 46 indicates that the maximum deflection of any point in relation to any other point on the circular support platform was 0.3 cm. The maximum deflection of the joints in the support platform carrying the cargo load was 0.7 cm and occurred at the transverse tank centerline due to the transverse elongation. The maximum contraction of the support platform occurred near the ship's longitudinal centerline and had a magnitude of 0.5 cm.

There were only four members that had a total normal stress in excess of the yield stress. Two of these members, 609 and 627, are vertical members in frame 195 and the high local bending stresses are due to the bowing caused by the application of the boundary conditions. The high stresses are completely unrealistic and are of no concern in the actual ship. The other two members, 672 and 687, have high stresses due to bending. This bending was caused by longitudinal contraction of the circular tank hold in the case of member 672 and the transverse elongation in the case of member 687. The stresses in these two members bears further investigation. However, it was the opinion of the writer

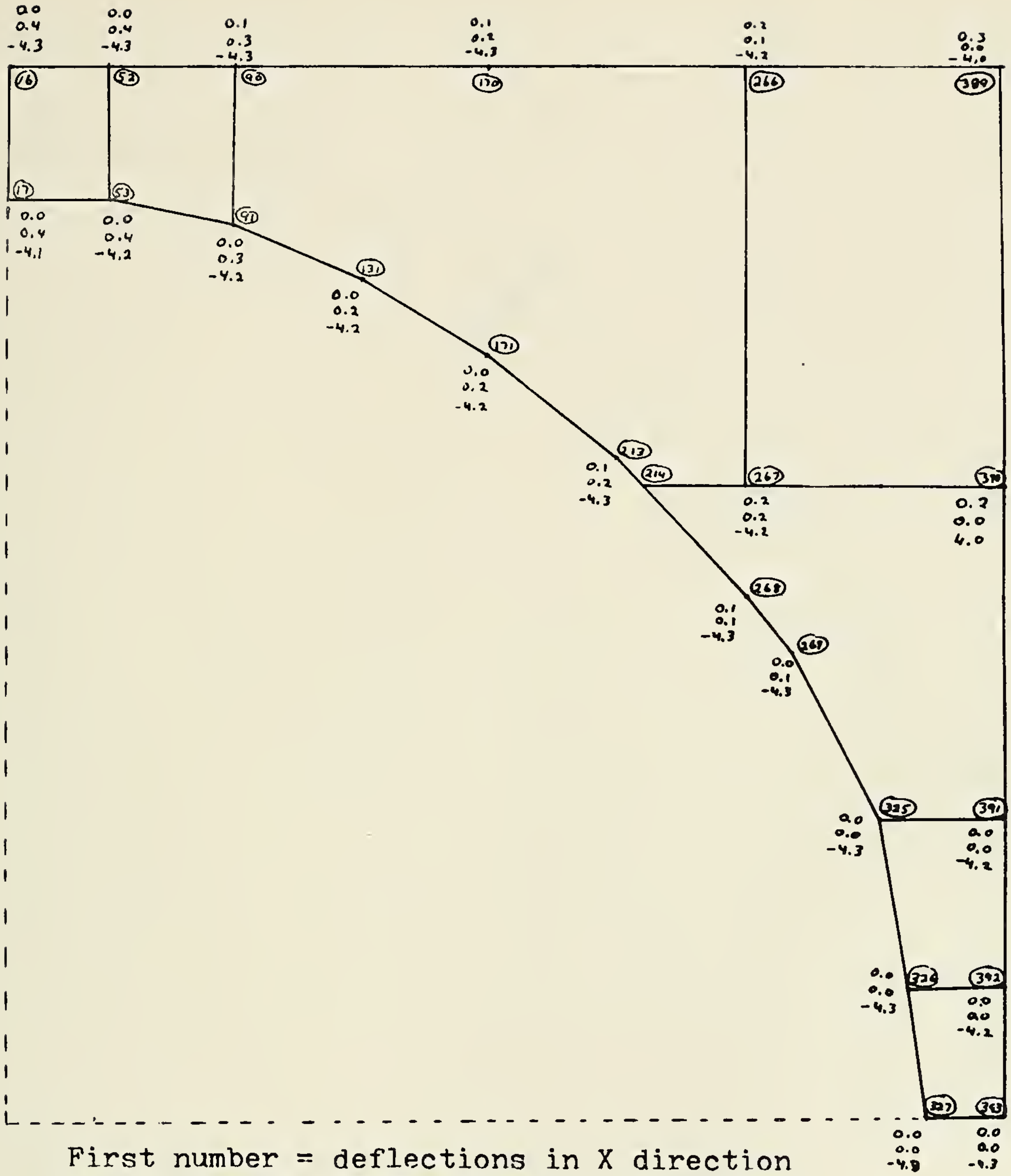


First number = deflections in X direction
Second number = deflections in Y direction
Third number = deflections in Z direction

FIGURE 44

BOTTOM DECK DEFLECTIONS

SAGGING CASE— RUN I

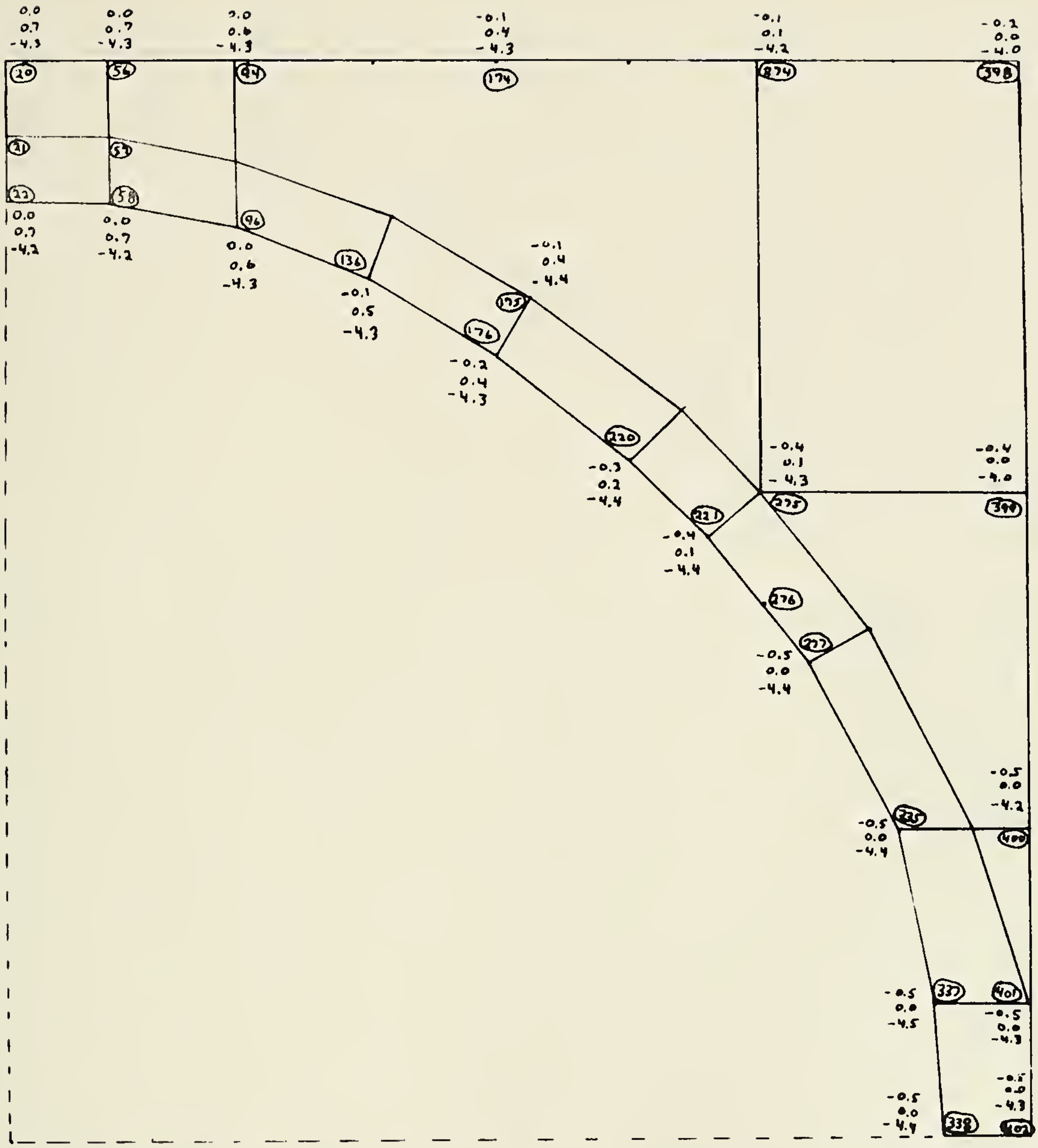


First number = deflections in X direction
Second number = deflections in Y direction
Third number = deflections in Z direction

FIGURE 45

SECOND DECK DEFLECTIONS

SAGGING CASE—RUN I

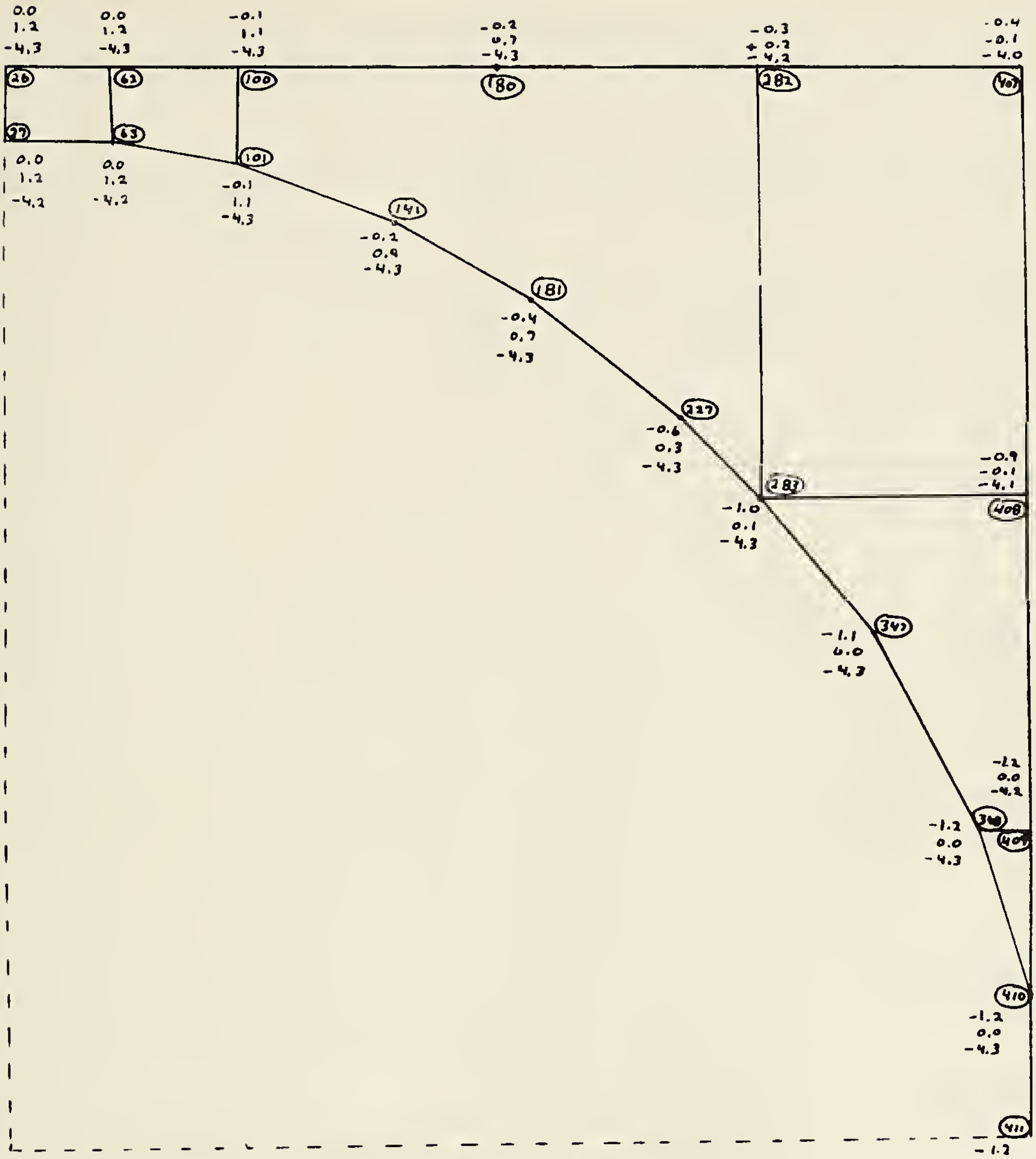


First number = deflections in X direction
Second number = deflections in Y direction
Third number = deflections in Z direction

FIGURE 46

THIRD DECK DEFLECTIONS

SAGGING CASE—RUN I

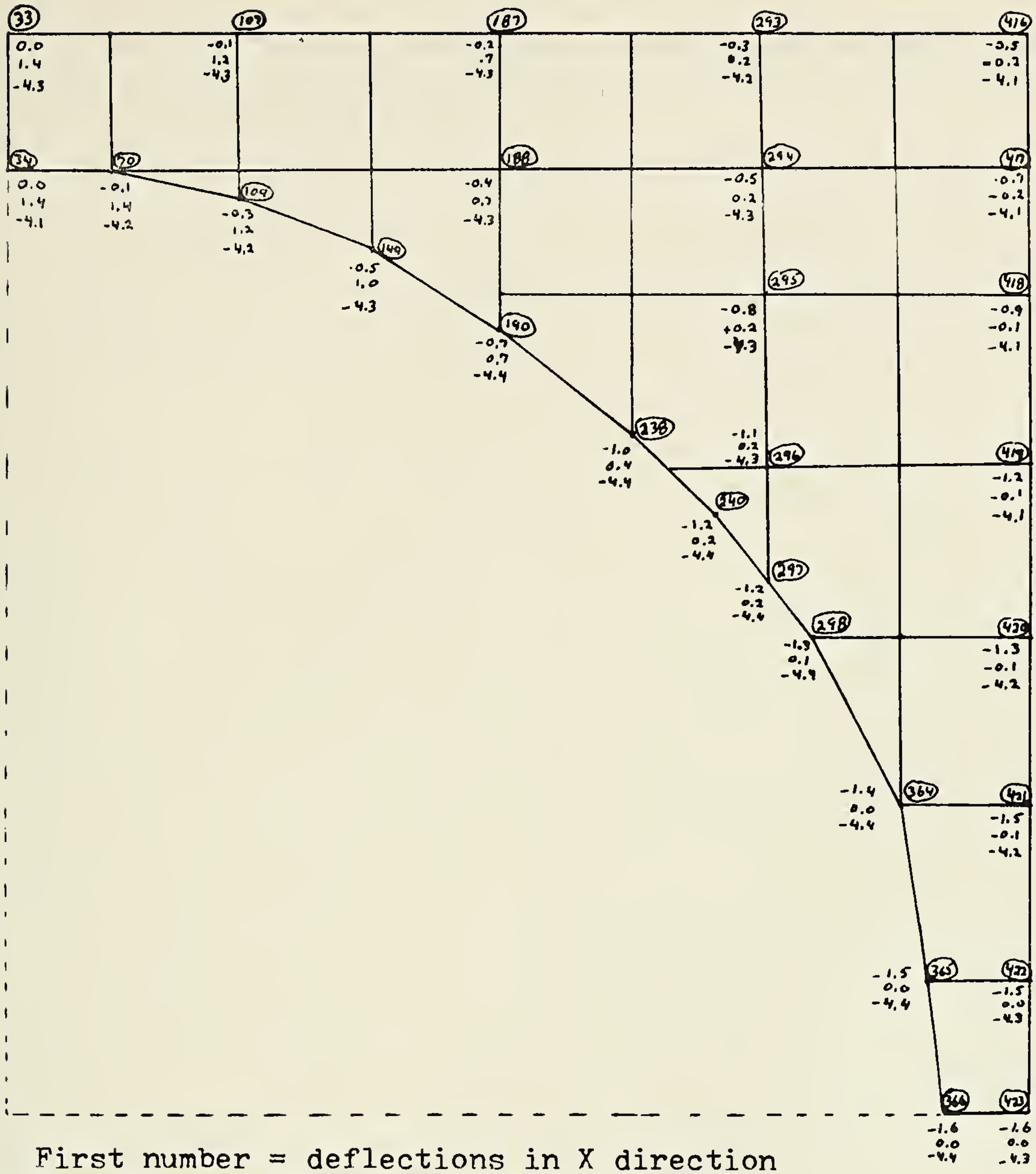


First number = deflections in X dierection
Second number = deflections in Y direction
Third number = deflections in Z direction

FIGURE 47

FOURTH DECK DEFLECTIONS

SAGGING CASE—RUN I



First number = deflections in X direction
Second number = deflections in Y direction
Third number = deflections in Z direction

FIGURE 48

MAIN DECK DEFLECTIONS

SAGGING CASE—RUN I

that these high bending stresses are the result of the beam model and are not realistic.

CONCLUSIONS

1. The ICES STRUDL program can be effectively utilized in the preliminary design phase to determine stresses and deflections of ships of unusual form for which traditional design criteria is unsatisfactory.

2. The beam element model used gave good results for the deflections of the circular support platform in the vertical direction. These results were basically independent of end effects due to the application of loads simulating the remainder of the ship. The maximum vertical deflection of any point in relation to any other point on the circular support platform was 0.6 centimeters for the conditions investigated.

3. The results for the magnitude of the transverse and longitudinal deflections of the circular platform were influenced by end conditions, particularly the distribution of forces simulating the bending moment. Upper limits were obtained for these magnitudes using a conservative distribution of forces.

4. The longitudinal stresses were also influenced by the end condition. However, it was possible to obtain an upper limit on the maximum value using a conservative distribution of boundary conditions. This maximum longitudinal

stress occurred in the main deck at the narrow portion of the hull as would be expected. The stress level in this area was of sufficient magnitude to warrant consideration of the use of high strength steel in this area.

5. The local member bending stress results obtained did not accurately reflect the actual case. Thls is due to the inability of beam elements to accurately model plates on a local scale. However, indications of areas with high bending stresses were obtained and these should be subjected to further investigation. Possible reduction of cutout sizes or additional flange reinforcement at the holes are possible cures if needed.

RECOMMENDATIONS

This thesis investigated the stresses and deflections for the hogging and sagging condition with the ship in an upright mode. It is recommended that additional work be carried out to determine the ships reaction to rolling and to torsion. The torsional stresses incurred when this ship is heading obliquely to a wave would be appreciable due to the small amount of main deck area.

A further recommendation is that the end effects be eliminated in any future work with this model or any other single tank section model. This can be accomplished by any of three ways:

(1) The model could be expanded in the longitudinal direction, thus eliminating the end effects on the quarter tank section of interest.

(2) A scale, strain guage equipped model could be constructed so that the correct distribution of longitudinal stresses in the main deck and web bulkheads at frame 195 can be determined.

(3) A macro-scale finite element program could be developed that would give as output the longitudinal stress distribution at the main deck.

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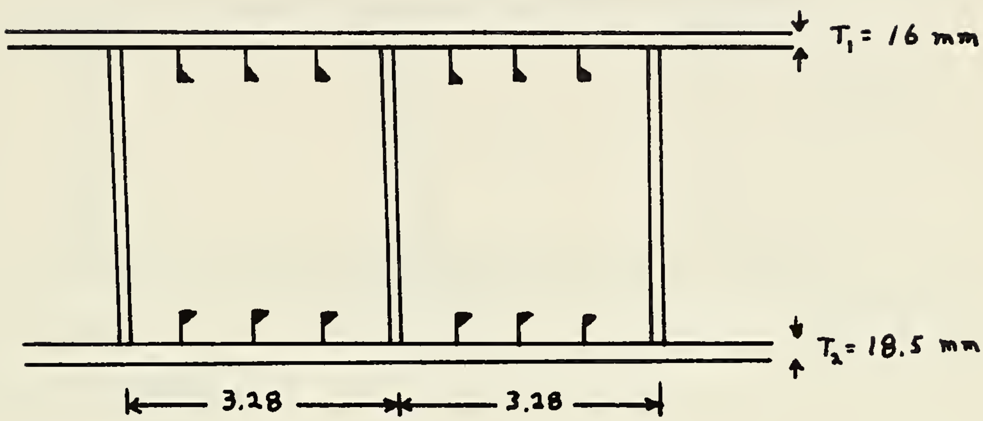
APPENDIX A

Sample Calculations

SAMPLE CALCULATION #1

EFFECTIVE THICKNESS OF PLATE

Double Bottom - Transverse Cross Section



stiffner spacing = 0.82 meters

frame spacing = 3.28 meters

cross sectional area of 400 X 14 HP stiffners = 6125 mm^2

cross sectional area of 400 X 15 HP stiffners = 8450 mm^2

$$\Delta t = \frac{\text{area of stiffner}}{\text{frame spacing}} \text{ X (no. stiffner between frames)}$$

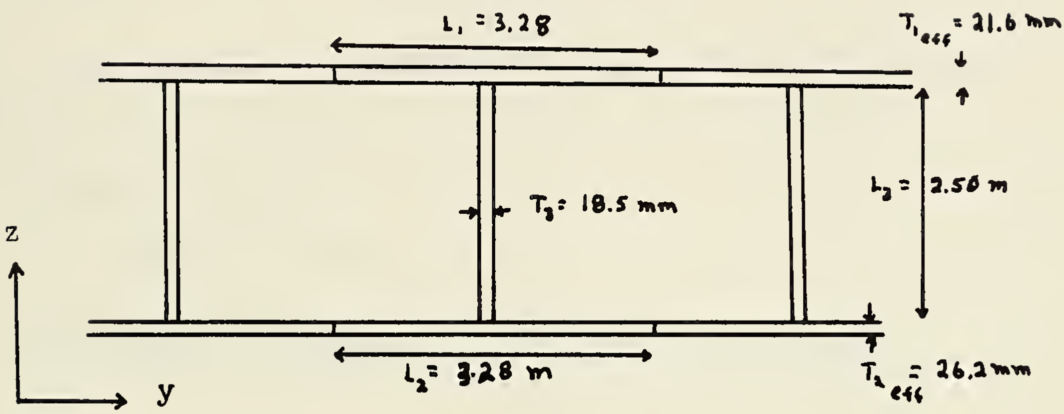
$$t_{1_{\text{effective}}} = 16 + \frac{6125}{3280} \text{ X } 3 = 21.6 \text{ mm}$$

$$t_{2_{\text{effective}}} = 18.5 + \frac{8450}{3280} \text{ X } 3 = 26.2 \text{ mm}$$

SAMPLE CALCULATION #2

MEMBER PROPERTIES

Double Bottom - Transverse Cross Section



local coordinates

The double bottom longitudinals may be idealized as beams as indicated by the solid lines above.

AX = cross-sectional area

$= (3.28)\ (.0216) + (2.50)\ (.0185) + (3.28)\ (.0262)$

$= .2030\ m^2$

AY = shear area in Y direction = area of flanges of beam

$= (3.28)\ (.0216) + (3.28)\ (.0262)$

$= .1567\ m^2$

AZ = shear area in Z direction = area of web of beam

$= (2.50)\ (.0185)$

$= .0462\ m^2$

IX = torsional rigidity

$= (1/3) \quad L(t_{eff})^3$

$= (1/3) \quad (3.28)(.0216)^3 + (3.28)(.0262)^3 + (2.50)(.0185)^3$

$= .000036 \text{ m}^4$

The effective breadth of the plating is equal to 60 times the thickness of the plate

in the y direction

$L_{1_{eff}} = 60(.0216) = 1.296$ m

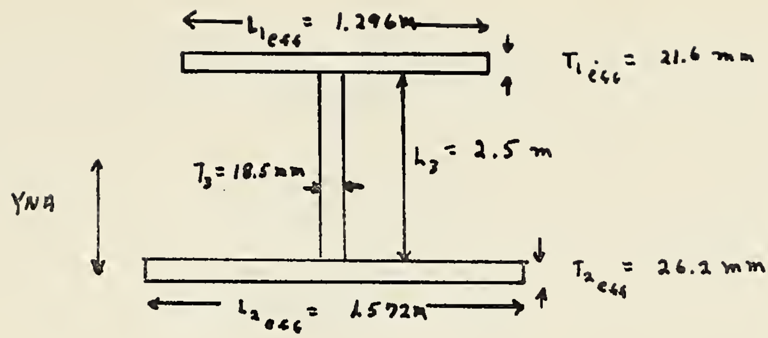
$L_{2_{eff}} = 60(.0262) = 1.572$ m

in the z direction

$L_{3_{eff}} = 60(.0185) = 1.11$ m

It is necessary to determine the y and z neutral axes in order to calculate the moments of inertia and section moduli for the y and z axes.

y neutral axis - it is necessary to use $L_{1_{eff}}$ and $L_{2_{eff}}$ to calculate the y neutral axis



YNA = distance from bottom of member to neutral axis

Y = distance from the y neutral axis to the extreme section

$$YNA = \frac{\Sigma\ (\text{areas})(\text{moment arms})}{\Sigma\ \text{areas}}$$

$$= \frac{(1.296)(.0216)(2.50) + (2.50)(.0185)(2.50/2)}{(1.296)(.0216) + (2.50)(.0185) + (1.572)(.0262)}$$

$$= 1.148\ \text{m}$$

IY = moment of inertia about y axis (using $L_{1_{eff}}$ and $L_{2_{eff}}$)

$$= (1/12)(.0185)(2.50)^3 + (.0216)(2.50 - 1.107)^2$$
$$+ (.0262)(1.572)(1.107)^2$$

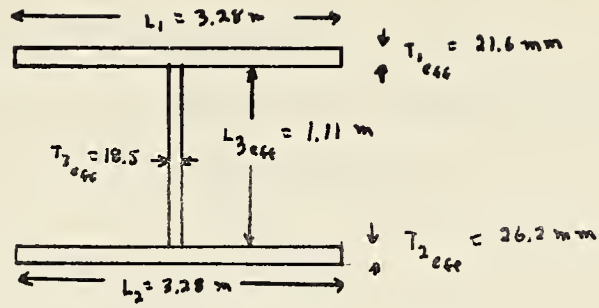
$$= .1322\ \text{m}^4$$

SY = section modulus about y axis

$$= \frac{IY}{Y}$$

$$= \frac{.1322}{1.352}$$

$$= .0978\ \text{m}^3$$



Z = distance from the z neutral axis to the extreme section

The z neutral axis is a vertical line through the horizontal centers of the three sections of the member.

IZ = moment of inertia about Z axis (use $L_{3_{eff}}$)

$$= (1/12)(.0216)(3.28)^3 + (1/12)(.0262)(3.28)^3$$

$$= .1406 \text{ m}^4$$

$$SZ = \frac{IZ}{Z}$$

$$= \frac{.1406}{1.64}$$

$$= .0857 \text{ m}^3$$

SAMPLE CALCULATION #3

The following load calculations are examples using values taken from Run III of the hogging case.

NOMENCLATURE AND VALUES

T = draft
= 15.2 meters

ρ = density of water
= 1.026 mtons/m^3

M = moment at frame 195
= 484,900 mtons-meter

Q = shear at frame 195
= 610 mtons

W = static steel weight of quarter tank section
= 74.55 tons/meter

a_g = acceleration of gravity
= 9.81 m/sec^2

a_h = acceleration due to heave
= 2.76 m/sec^2

a_p = acceleration due to pitching
= .04 m/sec^2

n = number of joints in beam model
= 208 joints

c = static load of cargo (quarter tank section)
= 3607 mtons

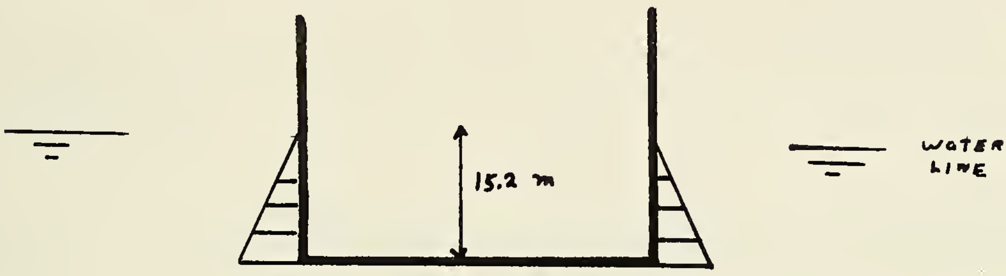
r_b = ratio of actual ship's bean to model's beam
= $\left(\frac{22.00}{20.78}\right) = 1.059$

r_l = ratio of actual quarter tank section length to model's length
= $(21.7/21.06) = 1.030$

Forces Due to Water Acting on the Hull

P = pressure on bottom hull = $(T)(\rho)$
= $(1.026)(15.2)$
= 15.6 mtons/cm^2

The water pressure loads were applied to the vertical members as indicated below.



F_m = (P)(member width)
= $(15.6)(2.55)$
= 39.78 mtons/cm

F_m for the vertical members at frame 228 is half of the above value due to symmetry conditions.

The loads on the bottom were divided such that half of the loads were applied to longitudinal members and half were applied to the transverse members.

F_w = (P)(member width)(r_b)
= $(15.6)(2.55)(1.1059)$
= 21.06 mtons/m

F_w for transverse members 1, 10, 19, 28, 38, 49, and 60 is one half the above value due to symmetry.

The forces on the longitudinal member were calculated in a similar fashion using

F_l = (P)(member width)(r_l)

Loads Due To Cargo

g = multiple of force felt by the quarter tank due to dynamic conditions

$= (a_g + a_n + a_p)/\ a_g$

$= (9.81 + 2.76 + .04)/\ 9.81$

$= 1.4$

F_c = dynamic cargo load = $(c)(g)$

$= (3607)(1.4)$

$= 5050$ mtons

There are 11 support joints, two of which only carry half of the load of the others, due to symmetry. Thus:

$f_c = 5050/(9 + .5 + .5)$

$= 50.5$ mtons/support joint

Loads Due To Steel Weight

$F_w = (w)(g)$

$= (74.55)(21.7)(1.4)$

$= 2265$ mtons

$f_w = F_w\ /\ n$

$= 2265/\ 208$

$= 10.89$ mtons/ joint

BOUNDARY LOADS - FRAME 195

The horizontal neutral axis was calculated to be located 10.5 meters above the bottom deck. The loads simulating the bending mement were assumed to be distributed as indicated in Figure 30. The moment that had to be applied to the quarter tank model was one half of the actual moment of the whole ship at frame 195. The forces applied above the neutral axis would form half of the couple. Thus to determine F_t and F_b

$$\frac{M}{(2)(2)} = 1/2 \text{ couple}$$

$$\frac{M}{4} = \frac{F_t}{3}(L_1)(L_2) + \frac{2F_tL_1}{(3)(2)}(L_3) + \left(\frac{F_tL_2}{2}\right)\left(\frac{2}{3}L_2\right) + \left(\frac{F_t}{3}\right)\left(\frac{L_2}{2}\right)\left(\frac{2}{3}L_2\right)$$

where L_1 = distance between the inner and outer webs = 8.27 m

L_2 = distance between the neutral axis and the main deck = 13.45 m

$$\frac{484,940}{4} = \frac{F_t}{3}(8.37)(13.4) + \frac{F_t}{3}(8.37)(13.45) + \frac{F_t}{3}(13.45)^2 + \frac{F_t}{9}(13.45)^2$$

F_t = 779.94 mtons/meter

$$\frac{M}{4} = F_b(L_3)(L_4) + (2)\frac{F_b L_4}{2}\left(\frac{2}{3} L_4\right)$$

where L_3 = width of double bottom
= 20.78 m

L_4 = distance from double bottom to neutral axis
= 10.5

$$\frac{484,940}{4} = F_b\ (20.78)(10.5) + F_b\ (10.5)^2\ (2/3)$$

F_b = 415.6 mtons/meter

The shear load at frame 195 for the quarter tank section was 610.5 mtons. This was distributed equally between the ten joints shown in Figure 30. Thus

$$q = Q/10$$
$$= \frac{610.5}{10} = 61.05 \text{ mtons}$$

Boundary Loads - Frame 228

In order to calculate the shear forces at frame 228 to prevent rigid body motion of the model it is necessary to make the summation of the forces in the vertical direction equal to zero.

F_z = summation of Z direction forces
= $Q - F_w - F_c$ + water on bottom hull
= 610.5 - 2265 - 5050 + 7437
= 742 mtons

$$q_{228} = -\frac{F_z}{10}$$

$$= -\frac{742}{10}$$

$$= -74.2 \text{ mtons/joint}$$

APPENDIX B

Computer Input for Run III of Hogging Case

```
STRUDL 'AMERTECH' 'LOADING 1'
DEBUG ALL
DUMP TIME
UNITS METERS MTONS DEGREES
TYPE SPACE FRAME
JOINT COORDINATES
$JT XCOORD YCOORD ZCOORD
1     0.0    20.78    0.0   S
2     0.0    18.06    0.0   S
3     0.0    15.69    0.0   S
4     0.0    12.41    0.0   S
5     0.0     9.13    0.0   S
6     0.0     5.85    0.0   S
7     0.0     2.57    0.0   S
8     0.0     0.00    0.0   S
16    0.0    20.78    7.6   S
17    0.0    18.06    7.6   S
20    0.0    20.78   14.0   S
21    0.0    19.34   14.0   S
22    0.0    18.06   14.0   S
26    0.0    20.78   20.25  S
27    0.0    19.34   20.25  S
33    0.0    20.78   23.95  S
34    0.0    18.06   23.95  S
37    1.94   20.78    0.0
38    1.94   18.06    0.0
39    1.94   15.69    0.0
40    1.94   12.41    0.0
41    1.94    9.13    0.0
42    1.94    5.85    0.0
43    1.94    2.57    0.0
44    1.94    0.00    0.0   S
52    1.94   20.78    7.6
53    1.94   18.06    7.6
56    1.94   20.78   14.0
57    1.94   19.34   14.0
```

58	1.94	18.06	14.0	
62	1.94	20.78	20.25	
63	1.94	19.34	20.25	
69	1.94	20.78	23.95	
70	1.94	18.06	23.95	
73	4.49	20.78	0.0	
74	4.49	18.06	0.0	
75	4.49	17.44	0.0	
76	4.49	15.69	0.0	
77	4.49	12.41	0.0	
78	4.49	9.13	0.0	
79	4.49	5.85	0.0	
80	4.49	2.57	0.0	
81	4.49	0.00	0.0	S
90	4.49	20.78	7.6	
91	4.49	17.44	7.6	
94	4.49	20.78	14.0	
95	4.49	18.72	14.0	
96	4.49	17.44	14.0	
100	4.49	20.78	20.25	
101	4.49	18.72	20.25	
107	4.49	20.78	23.95	
108	4.49	18.06	23.95	
109	4.49	17.44	23.95	
113	7.04	20.78	0.0	
114	7.04	18.06	0.0	
115	7.04	16.39	0.0	
116	7.04	15.69	0.0	
117	7.04	12.41	0.0	
118	7.04	9.13	0.0	
119	7.04	5.85	0.0	
120	7.04	2.57	0.0	
121	7.04	0.00	0.0	S
130	7.04	20.78	7.6	
131	7.04	16.39	7.6	
134	7.04	20.78	14.0	

135	7.63	17.57	14.0	
136	7.04	16.39	14.0	
140	7.04	20.78	20.25	
141	7.63	17.57	20.25	
147	7.04	20.78	23.95	
148	7.04	18.06	23.95	
149	7.04	16.39	23.95	
153	9.59	20.78	0.0	
154	9.59	18.06	0.0	
155	9.59	15.69	0.0	
156	9.59	15.09	0.0	
157	9.59	12.41	0.0	
158	9.59	9.13	0.0	
159	9.59	5.85	0.0	
160	9.59	2.57	0.0	
161	9.59	0.00	0.0	S
170	9.59	20.78	7.6	
171	9.59	15.09	7.6	
174	9.59	20.78	14.0	
175	10.27	16.19	14.0	
176	9.59	15.09	14.0	
180	9.59	20.78	20.25	
181	10.27	16.19	20.25	
187	9.59	20.78	23.95	
188	9.59	18.06	23.95	
189	9.59	15.69	23.95	
190	9.59	15.09	23.95	
195	12.14	20.78	0.0	
196	12.14	18.06	0.0	
197	12.14	15.69	0.0	
198	12.14	13.21	0.0	
199	12.14	12.41	0.0	
200	12.14	9.13	0.0	
201	12.14	5.85	0.0	
202	12.14	2.57	0.0	
203	12.14	0.00	0.0	S

212	12.14	20.78	7.6	
213	12.14	13.21	7.6	
214	12.80	12.41	7.6	
218	12.14	20.78	14.0	
219	12.82	14.32	14.0	
220	12.14	13.21	14.0	
221	13.63	11.61	14.0	
226	12.14	20.78	20.25	
227	13.63	14.32	20.25	
235	12.14	20.78	23.95	
236	12.14	16.06	23.95	
237	12.14	15.69	23.95	
238	12.14	13.21	23.95	
239	12.80	12.41	23.95	
240	13.76	11.51	23.95	
247	14.69	20.78	0.0	
248	14.69	18.06	0.0	
249	14.69	15.69	0.0	
250	14.69	12.41	0.0	
251	14.69	10.31	0.0	
252	14.69	9.13	0.0	
253	15.76	9.13	0.0	
254	14.69	5.85	0.0	
255	14.69	2.57	0.0	
256	14.69	0.00	0.0	S
266	14.69	20.78	7.6	
267	14.69	12.41	7.6	
268	14.69	10.31	7.6	
269	15.76	9.13	7.6	
274	14.69	20.78	14.0	
275	14.69	12.41	14.0	
276	14.69	10.31	14.0	
277	15.76	9.13	14.0	
282	14.69	20.78	20.25	
283	14.69	12.41	20.25	
284	15.81	11.14	20.25	

293	14.69	20.78	23.95	
294	14.69	18.06	23.95	
295	14.69	15.69	23.95	
296	14.69	12.41	23.95	
297	14.69	10.31	23.95	
298	15.76	9.13	23.95	
305	17.24	20.78	0.0	
306	17.24	18.06	0.0	
307	17.24	15.69	0.0	
308	17.24	12.41	0.0	
309	17.24	9.13	0.0	
310	17.24	5.85	0.0	
311	17.24	2.57	0.0	
312	17.95	2.57	0.0	
313	17.24	0.00	0.0	S
314	18.32	0.00	0.0	S
323	17.24	20.78	7.6	
324	17.24	12.41	7.6	
325	17.24	5.85	7.6	
326	17.95	2.57	7.6	
327	18.32	0.00	7.6	S
332	17.24	20.78	14.0	
333	17.24	12.41	14.0	
334	16.87	9.77	14.0	
335	17.24	5.85	14.0	
336	18.65	5.85	14.0	
337	17.95	2.57	14.0	
338	18.32	0.0	14.0	S
345	17.24	20.78	20.25	
346	17.24	12.41	20.25	
347	16.87	9.77	20.25	
348	18.65	5.85	20.25	
359	17.24	20.78	23.95	
360	17.24	18.06	23.95	
361	17.24	15.69	23.95	
362	17.24	12.41	23.95	

363	17.24	9.13	23.95	
364	17.24	5.85	23.95	
365	17.95	2.57	23.95	
366	18.32	0.0	23.95	S
374	19.79	20.78	0.0	
375	19.79	18.06	0.0	
376	19.79	15.69	0.0	
377	19.79	12.41	0.0	
378	19.79	9.13	0.0	
379	19.79	5.85	0.0	
380	19.79	2.57	0.0	
381	19.79	0.00	0.0	S
389	19.79	20.78	7.6	
390	19.79	12.41	7.6	
391	19.79	5.85	7.6	
392	19.79	2.57	7.6	
393	19.79	0.00	7.6	S
398	19.79	20.78	14.0	
399	19.79	12.41	14.0	
400	19.79	5.85	14.0	
401	19.79	2.57	14.0	
402	19.79	0.00	14.0	S
407	19.79	20.78	20.25	
408	19.79	12.41	20.25	
409	19.79	5.85	20.25	
410	19.79	2.57	20.25	
411	19.79	0.00	20.25	S
416	19.79	20.78	23.95	
417	19.79	18.06	23.95	
418	19.79	15.69	23.95	
419	19.79	12.41	23.95	
420	19.79	9.13	23.95	
421	19.79	5.85	23.95	
422	19.79	2.57	23.95	
423	19.79	0.00	23.95	S

$

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JOINT RELEASES
44 81 121 161 203 256 313 314 381 327 393 338 402 411 366 423 FORCES X Z MOM Y
1 TO 7 16 17 20 21 22 26 27 33 34 FORCE Y Z MOM X
$
MEMBER INCIDENCIES
$ DOUBLE BOTTOM TRANS DIR
1 8 7
2 44 43
3 81 80
4 121 120
5 161 160
6 203 202
7 256 255
8 315 311
9 381 380
10 7 6
11 43 42
12 80 79
13 120 119
14 160 159
15 202 201
16 255 254
17 311 310
18 380 379
19 6 5
20 42 41
21 79 78
22 119 118
23 159 158
24 201 200
25 254 252
26 310 309
27 379 378
28 5 4
29 41 40
30 78 77
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31	118	117
32	158	157
33	200	199
34	251	250
35	252	251
36	309	308
37	378	377
38	4	3
39	40	39
40	77	76
41	117	116
42	156	155
43	157	156
44	199	198
45	198	197
46	250	249
47	308	307
48	377	376
49	3	2
50	39	38
51	75	74
52	76	75
53	115	114
54	116	115
55	155	154
56	197	196
57	249	248
58	307	306
59	376	375
60	2	1
61	38	37
62	74	73
63	114	113
64	154	153
65	196	195
66	248	247

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67 306 305
68 375 374
$DOUBLE BOTTOM LONG DIR
69 6 44
70 44 81
71 81 121
72 121 161
73 161 203
74 203 256
75 256 313
76 313 314
77 314 381
78 7 43
79 43 80
80 80 120
81 120 160
82 160 202
83 202 255
84 255 311
85 311 312
86 312 380
87 6 42
88 42 79
89 79 119
90 119 159
91 159 201
92 201 254
93 254 310
94 310 379
95 5 41
96 41 78
97 78 118
98 118 158
99 158 200
100 200 252
101 252 253
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102 253 309
103 309 378
104 4 40
105 40 77
106 77 117
107 117 157
108 157 199
109 199 250
110 250 308
111 308 377
112 3 39
113 39 76
114 76 116
115 116 155
116 155 197
117 197 249
118 249 307
119 307 376
120 2 38
121 38 74
122 74 114
123 114 154
124 154 196
125 196 248
126 248 306
127 306 375
128 1 37
129 37 73
130 73 113
131 113 153
132 153 195
133 195 247
134 247 305
135 305 374
$ B-B DECK LONG DIR
201 16 52
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202 52 90
203 90 130
204 130 170
205 170 212
206 212 266
207 266 323
208 323 389
209 214 267
210 267 324
211 324 390
212 325 391
213 326 392
214 327 393
$ B-B DECK TRANS DIR
215 17 16
216 53 52
217 267 266
218 390 389
219 391 390
220 392 391
221 393 392
$ B-B DECK SUPPORT PLATFORM
222 17 53
223 53 91
224 91 131
225 131 171
226 171 213
227 213 214
228 214 268
229 268 269
230 269 325
231 325 326
232 326 327
233 91 90
$ C-D DECK LONG DIR
301 20 56
```

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302 56 94
303 94 134
304 134 174
305 174 218
306 218 274
307 274 332
308 332 398
309 275 333
310 333 399
311 335 336
312 336 400
313 337 401
314 338 402
$DECK C-D TRANS DIR
315 21 20
316 22 21
317 57 56
318 56 57
319 95 94
320 96 95
321 275 274
322 399 398
$ NUMBERS 323 AND 324 LEFT OUT
325 400 399
326 401 400
327 402 401
$ DECK C-D TANK HOLD WALL HORIZONTAL PLANE
328 21 57
329 57 95
330 95 135
331 135 175
332 175 219
333 219 275
334 275 334
335 334 336
336 336 401
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$ DECK C-D SUPPORT PLATFORM HORIZ PLANE
337 22 58
338 58 96
339 96 136
340 136 176
341 176 220
342 220 221
343 221 276
344 276 277
345 277 335
346 335 337
347 337 338
348 136 135
349 176 175
350 220 219
351 221 275
352 277 334
$ DECK E-E LONG DIR
401 26 62
402 62 100
403 100 140
404 140 180
405 180 226
406 226 282
407 282 345
408 345 407
409 283 346
410 346 408
411 348 409
$ DECK E-E TRANS DIR
412 27 26
413 63 62
414 101 100
415 283 282
416 408 407
$ NUMBERS 417 AND 418 LEFT OUT
```

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419 409 408
420 410 409
421 411 410
$ DECK E-E TANK HOLD HORIZ PLANE
422 27 63
423 63 101
424 101 141
425 141 181
426 181 227
427 227 283
428 283 284
429 284 347
430 347 348
431 348 410
$ MAIN DECK LONG DIR
501 33 69
502 69 107
503 107 147
504 147 187
505 187 235
506 235 293
507 293 359
508 359 416
$ NUMBERS 509 AND 511 LEFT OUT
510 34 70
512 70 108
513 108 148
514 148 188
515 188 236
516 236 294
517 294 360
518 360 417
519 189 237
520 237 295
521 295 361
522 361 418
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523 239 296
524 296 362
$ NUMBER 525 LEFT OUT
526 362 419
527 298 363
528 363 420
529 364 421
530 365 422
531 366 423
$ MAIN DECK TRANS DIR
532 34 33
533 70 69
534 108 107
535 148 147
536 188 187
537 236 235
539 360 359
538 294 293
540 417 416
541 109 108
542 149 148
543 189 188
544 237 236
$ NUMBER 545 LEFT OUT
546 295 294
547 361 360
548 418 417
549 190 189
550 238 237
551 296 295
552 362 361
553 419 418
554 297 296
555 363 362
556 420 419
557 364 363
```

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558 421 420
559 422 421
560 423 422
$ MAIN DECK TANK HOLD WALL HORIZ PLANE
561 70 109
562 109 149
563 149 190
564 190 238
565 238 239
566 239 240
567 240 297
568 297 298
569 298 364
570 364 365
571 365 366
$ VERTICAL MEMBERS OUTER HULL
601 1 16
602 37 52
603 73 90
604 113 130
605 153 170
606 195 212
607 247 266
608 305 323
609 374 389
610 16 20
611 52 56
612 90 94
613 130 134
614 170 174
615 212 218
616 266 274
617 323 332
618 389 398
619 20 26
620 56 62
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621 94 100
622 134 140
623 174 180
624 218 226
625 274 282
626 332 345
627 393 407
628 26 33
629 62 69
630 100 107
631 140 147
632 180 187
633 226 235
634 282 293
635 345 359
636 407 416
$ VERTICAL MEMBERS INNER WEB
$ NUMBERS 637-639 LEFT OUT
640 250 267
641 306 324
642 377 390
643 267 275
644 324 333
645 390 399
646 275 283
647 333 346
648 399 408
649 283 296
650 346 362
651 408 419
$VERTICAL MEMBERS TRANS SECTION
652 381 393
653 380 392
654 379 391
655 393 402
656 392 401
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657 391 400
658 402 411
659 401 410
660 400 409
661 411 423
662 410 422
663 409 421
$VERTICAL MEMBERS SUPPORT PLATFORM
664 2 17
665 38 53
666 75 91
667 115 131
668 156 171
669 198 213
670 251 268
671 253 269
672 310 325
673 312 326
674 314 327
675 17 22
676 53 58
677 91 96
678 131 136
679 171 176
680 213 220
681 268 276
682 269 277
683 325 335
684 326 337
685 327 338
$ VERTICAL MEMBERS TANK HOLD
686 21 27
687 57 63
688 95 101
689 135 141
690 175 181
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691 219 227
692 275 283
693 334 347
694 336 348
$ NUMBERS 695-696 LEFT OUT
697 27 34
698 63 70
699 101 109
700 141 149
701 181 190
702 227 238
703 283 240
704 347 298
705 348 364
$
MEMBER PROPERTIES PRISMATIC
1    AX .0611 AY .0448 AZ .0163 IX .00001 IY .03750 IZ .0071  SY .0284  SZ .0105
2    AX .1221 AY .0896 AZ .0325 IX .00001 IY .075   IZ .0489  SY .0568  SZ .0383
3    AX .1221 AY .0896 AZ .0325 IX .00001 IY .075   IZ .0489  SY .0568  SZ .0383
4    AX .1221 AY .0896 AZ .0325 IX .00001 IY .075   IZ .0489  SY .0568  SZ .0383
5    AX .1221 AY .0896 AZ .0325 IX .00001 IY .075   IZ .0489  SY .0568  SZ .0383
6    AX .1221 AY .0896 AZ .0325 IX .00001 IY .075   IZ .0489  SY .0568  SZ .0383
7    AX .1221 AY .0896 AZ .0325 IX .00001 IY .075   IZ .0489  SY .0568  SZ .0383
8    AX .1221 AY .0896 AZ .0325 IX .00001 IY .075   IZ .0489  SY .0568  SZ .0383
9    AX .1221 AY .0896 AZ .0325 IX .00001 IY .075   IZ .0489  SY .0568  SZ .0383
10   AX .0611 AY .0448 AZ .0163 IX .00001 IY .03750 IZ .0071  SY .0284  SZ .0105
11   AX .1221 AY .0896 AZ .0325 IX .00001 IY .075   IZ .0489  SY .0568  SZ .0383
12   AX .1221 AY .0896 AZ .0325 IX .00001 IY .075   IZ .0489  SY .0568  SZ .0383
13   AX .1221 AY .0896 AZ .0325 IX .00001 IY .075   IZ .0489  SY .0568  SZ .0383
14   AX .1221 AY .0896 AZ .0325 IX .00001 IY .075   IZ .0489  SY .0568  SZ .0383
15   AX .1221 AY .0896 AZ .0325 IX .00001 IY .075   IZ .0489  SY .0568  SZ .0383
16   AX .1221 AY .0896 AZ .0325 IX .00001 IY .075   IZ .0489  SY .0568  SZ .0383
17   AX .1221 AY .0896 AZ .0325 IX .00001 IY .075   IZ .0489  SY .0568  SZ .0383
18   AX .1221 AY .0896 AZ .0325 IX .00001 IY .075   IZ .0489  SY .0568  SZ .0383
19   AX .0611 AY .0448 AZ .0163 IX .00001 IY .03750 IZ .0071  SY .0284  SZ .0105
20   AX .1221 AY .0896 AZ .0325 IX .00001 IY .075   IZ .0489  SY .0568  SZ .0383
```

21	AX	.1221	AY	.0896	AZ	.0325	IX	.00001	IY	.075	IZ	.0489	SY	.0568	SZ	.0383
22	AX	.1221	AY	.0896	AZ	.0325	IX	.00001	IY	.075	IZ	.0489	SY	.0568	SZ	.0383
23	AX	.1221	AY	.0896	AZ	.0325	IX	.00001	IY	.075	IZ	.0489	SY	.0568	SZ	.0383
24	AX	.1221	AY	.0896	AZ	.0325	IX	.00001	IY	.075	IZ	.0489	SY	.0568	SZ	.0383
25	AX	.1221	AY	.0896	AZ	.0325	IX	.00001	IY	.075	IZ	.0489	SY	.0568	SZ	.0383
26	AX	.1221	AY	.0896	AZ	.0325	IX	.00001	IY	.075	IZ	.0489	SY	.0568	SZ	.0383
27	AX	.1221	AY	.0896	AZ	.0325	IX	.00001	IY	.075	IZ	.0489	SY	.0568	SZ	.0383
28	AX	.0631	AY	.0448	AZ	.0183	IX	.00001	IY	.04816	IZ	.0071	SY	.0324	SZ	.0105
29	AX	.1261	AY	.0896	AZ	.0365	IX	.00001	IY	.0968	IZ	.0489	SY	.0651	SZ	.0382
30	AX	.1261	AY	.0896	AZ	.0365	IX	.00001	IY	.0968	IZ	.0489	SY	.0651	SZ	.0382
31	AX	.1261	AY	.0896	AZ	.0365	IX	.00001	IY	.0968	IZ	.0489	SY	.0651	SZ	.0382
32	AX	.1261	AY	.0896	AZ	.0365	IX	.00001	IY	.0968	IZ	.0489	SY	.0651	SZ	.0382
33	AX	.1261	AY	.0896	AZ	.0365	IX	.00001	IY	.0968	IZ	.0489	SY	.0651	SZ	.0382
34	AX	.1261	AY	.0896	AZ	.0365	IX	.00001	IY	.0968	IZ	.0489	SY	.0651	SZ	.0382
35	AX	.1261	AY	.0896	AZ	.0365	IX	.00001	IY	.0968	IZ	.0489	SY	.0651	SZ	.0382
36	AX	.1261	AY	.0896	AZ	.0365	IX	.00001	IY	.0968	IZ	.0489	SY	.0651	SZ	.0382
37	AX	.1261	AY	.0896	AZ	.0365	IX	.00001	IY	.0968	IZ	.0489	SY	.0651	SZ	.0382
38	AX	.0664	AY	.0448	AZ	.0216	IX	.00001	IY	.0703	IZ	.0071	SY	.0403	SZ	.0105
39	AX	.1328	AY	.0896	AZ	.0432	IX	.00001	IY	.1406	IZ	.0489	SY	.0805	SZ	.03
40	AX	.1328	AY	.0896	AZ	.0432	IX	.00001	IY	.1406	IZ	.0489	SY	.0805	SZ	.03
41	AX	.1328	AY	.0896	AZ	.0432	IX	.00001	IY	.1406	IZ	.0489	SY	.0805	SZ	.03
42	AX	.1328	AY	.0896	AZ	.0432	IX	.00001	IY	.1406	IZ	.0489	SY	.0805	SZ	.03
43	AX	.1328	AY	.0896	AZ	.0432	IX	.00001	IY	.1406	IZ	.0489	SY	.0805	SZ	.03
44	AX	.1328	AY	.0896	AZ	.0432	IX	.00001	IY	.1406	IZ	.0489	SY	.0805	SZ	.03
45	AX	.1328	AY	.0896	AZ	.0432	IX	.00001	IY	.1406	IZ	.0489	SY	.0805	SZ	.03
46	AX	.1328	AY	.0896	AZ	.0432	IX	.00001	IY	.1406	IZ	.0489	SY	.0805	SZ	.03
47	AX	.1328	AY	.0896	AZ	.0432	IX	.00001	IY	.1406	IZ	.0489	SY	.0805	SZ	.03
48	AX	.1618	AY	.0896	AZ	.0722	IX	.00001	IY	.3273	IZ	.0489	SY	.1019	SZ	.0382
49	AX	.0694	AY	.0448	AZ	.0246	IX	.00001	IY	.0947	IZ	.0071	SY	.0478	SZ	.0105
50	AX	.1387	AY	.0896	AZ	.0491	IX	.00001	IY	.1894	IZ	.0489	SY	.0956	SZ	.0382
51	AX	.1387	AY	.0896	AZ	.0491	IX	.00001	IY	.1894	IZ	.0489	SY	.0956	SZ	.0382
52	AX	.1387	AY	.0896	AZ	.0491	IX	.00001	IY	.1894	IZ	.0489	SY	.0956	SZ	.0382
53	AX	.1387	AY	.0896	AZ	.0491	IX	.00001	IY	.1894	IZ	.0489	SY	.0956	SZ	.0382
54	AX	.1387	AY	.0896	AZ	.0491	IX	.00001	IY	.1894	IZ	.0489	SY	.0956	SZ	.0382
55	AX	.1387	AY	.0896	AZ	.0491	IX	.00001	IY	.1894	IZ	.0489	SY	.0956	SZ	.0382
56	AX	.1387	AY	.0896	AZ	.0491	IX	.00001	IY	.1894	IZ	.0489	SY	.0956	SZ	.0382

57	AX	.1387	AY	.0896	AZ	.0491	IX	.00001	IY	.1894	IZ	.0489	SY	.0956	SZ	.0382
58	AX	.1387	AY	.0896	AZ	.0491	IX	.00001	IY	.1894	IZ	.0489	SY	.0956	SZ	.0382
59	AX	.1618	AY	.0896	AZ	.0722	IX	.00001	IY	.345	IZ	.0489	SY	.1097	SZ	.0382
60	AX	.0705	AY	.0448	AZ	.0257	IX	.00001	IY	.1049	IZ	.0071	SY	.0508	SZ	.0105
61	AX	.1319	AY	.0806	AZ	.0514	IX	.00001	IY	.195	IZ	.044	SY	.0907	SZ	.0344
62	AX	.1319	AY	.0806	AZ	.0514	IX	.00001	IY	.195	IZ	.044	SY	.0907	SZ	.0344
63	AX	.1319	AY	.0806	AZ	.0514	IX	.00001	IY	.195	IZ	.044	SY	.0907	SZ	.0344
64	AX	.1319	AY	.0806	AZ	.0514	IX	.00001	IY	.195	IZ	.044	SY	.0907	SZ	.0344
65	AX	.1319	AY	.0806	AZ	.0514	IX	.00001	IY	.195	IZ	.044	SY	.0907	SZ	.0344
66	AX	.1319	AY	.0806	AZ	.0514	IX	.00001	IY	.195	IZ	.044	SY	.0907	SZ	.0344
67	AX	.1319	AY	.0806	AZ	.0514	IX	.00001	IY	.195	IZ	.044	SY	.0907	SZ	.0344
68	AX	.173	AY	.090	AZ	.0834	IX	.00002	IY	.335	IZ	.0489	SY	.1155	SZ	.0382
69	AX	.1271	AY	.1039	AZ	.0233	IX	.00002	IY	.0788	IZ	.0202	SY	.0509	SZ	.0217
70	AX	.1271	AY	.1039	AZ	.0233	IX	.00002	IY	.0788	IZ	.0202	SY	.0509	SZ	.0217
71	AX	.1271	AY	.1039	AZ	.0233	IX	.00002	IY	.0788	IZ	.0202	SY	.0509	SZ	.0217
72	AX	.1271	AY	.1039	AZ	.0233	IX	.00002	IY	.0788	IZ	.0202	SY	.0509	SZ	.0217
73	AX	.1271	AY	.1039	AZ	.0233	IX	.00002	IY	.0788	IZ	.0202	SY	.0509	SZ	.0217
74	AX	.1271	AY	.1039	AZ	.0233	IX	.00002	IY	.0788	IZ	.0202	SY	.0509	SZ	.0217
75	AX	.1271	AY	.1039	AZ	.0233	IX	.00002	IY	.0788	IZ	.0202	SY	.0509	SZ	.0217
76	AX	.1271	AY	.1039	AZ	.0233	IX	.00002	IY	.0788	IZ	.0202	SY	.0509	SZ	.0217
77	AX	.1519	AY	.1039	AZ	.0552	IX	.00002	IY	.281	IZ	.0214	SY	.0767	SZ	.0221
78	AX	.203	AY	.157	AZ	.0462	IX	.00004	IY	.1322	IZ	.14	SY	.0978	SZ	.0857
79	AX	.203	AY	.157	AZ	.0462	IX	.00004	IY	.1322	IZ	.14	SY	.0978	SZ	.0857
80	AX	.203	AY	.157	AZ	.0462	IX	.00004	IY	.1322	IZ	.14	SY	.0978	SZ	.0857
81	AX	.203	AY	.157	AZ	.0462	IX	.00004	IY	.1322	IZ	.14	SY	.0978	SZ	.0857
82	AX	.203	AY	.157	AZ	.0462	IX	.00004	IY	.1322	IZ	.14	SY	.0978	SZ	.0857
83	AX	.203	AY	.157	AZ	.0462	IX	.00004	IY	.1322	IZ	.14	SY	.0978	SZ	.0857
84	AX	.203	AY	.157	AZ	.0462	IX	.00004	IY	.1322	IZ	.14	SY	.0978	SZ	.0857
85	AX	.203	AY	.157	AZ	.0462	IX	.00004	IY	.1322	IZ	.14	SY	.0978	SZ	.0857
86	AX	.264	AY	.157	AZ	.107	IX	.00004	IY	.408	IZ	.14	SY	.1195	SZ	.0857
87	AX	.203	AY	.157	AZ	.0462	IX	.00004	IY	.1322	IZ	.14	SY	.0978	SZ	.0857
88	AX	.203	AY	.157	AZ	.0462	IX	.00004	IY	.1322	IZ	.14	SY	.0978	SZ	.0857
89	AX	.203	AY	.157	AZ	.0462	IX	.00004	IY	.1322	IZ	.14	SY	.0978	SZ	.0857
90	AX	.203	AY	.157	AZ	.0462	IX	.00004	IY	.1322	IZ	.14	SY	.0978	SZ	.0857
91	AX	.203	AY	.157	AZ	.0462	IX	.00004	IY	.1322	IZ	.14	SY	.0978	SZ	.0857
92	AX	.203	AY	.157	AZ	.0462	IX	.00004	IY	.1322	IZ	.14	SY	.0978	SZ	.0857

93	AX	.203	AY	.157	AZ	.0462	IX	.00004	IY	.1322	IZ	.14	SY	.0978	SZ	.0857
94	AX	.264	AY	.157	AZ	.107	IX	.00004	IY	.408	IZ	.14	SY	.1195	SZ	.0857
95	AX	.204	AY	.157	AZ	.0471	IX	.00004	IY	.138	IZ	.14	SY	.1	SZ	.0857
96	AX	.204	AY	.157	AZ	.0471	IX	.00004	IY	.138	IZ	.14	SY	.1	SZ	.0857
97	AX	.204	AY	.157	AZ	.0471	IX	.00004	IY	.138	IZ	.14	SY	.1	SZ	.0857
98	AX	.204	AY	.157	AZ	.0471	IX	.00004	IY	.138	IZ	.14	SY	.1	SZ	.0857
99	AX	.204	AY	.157	AZ	.0471	IX	.00004	IY	.138	IZ	.14	SY	.1	SZ	.0857
100	AX	.204	AY	.157	AZ	.0471	IX	.00004	IY	.138	IZ	.14	SY	.1	SZ	.0857
101	AX	.204	AY	.157	AZ	.0471	IX	.00004	IY	.138	IZ	.14	SY	.1	SZ	.0857
102	AX	.204	AY	.157	AZ	.0471	IX	.00004	IY	.138	IZ	.14	SY	.1	SZ	.0857
103	AX	.204	AY	.157	AZ	.0471	IX	.00004	IY	.138	IZ	.14	SY	.1	SZ	.0857
104	AX	.2134	AY	.1568	AZ	.0566	IX	.00004	IY	.2036	IZ	.1404	SY	.1232	SZ	.0857
105	AX	.2134	AY	.1568	AZ	.0566	IX	.00004	IY	.2036	IZ	.1404	SY	.1232	SZ	.0857
106	AX	.2134	AY	.1568	AZ	.0566	IX	.00004	IY	.2036	IZ	.1404	SY	.1232	SZ	.0857
107	AX	.2134	AY	.1568	AZ	.0566	IX	.00004	IY	.2036	IZ	.1404	SY	.1232	SZ	.0857
108	AX	.2134	AY	.1568	AZ	.0566	IX	.00004	IY	.2036	IZ	.1404	SY	.1232	SZ	.0857
109	AX	.2134	AY	.1568	AZ	.0566	IX	.00004	IY	.2036	IZ	.1404	SY	.1232	SZ	.0857
110	AX	.2678	AY	.1568	AZ	.111	IX	.00004	IY	.5355	IZ	.1406	SY	.1605	SZ	.0857
111	AX	.2678	AY	.1568	AZ	.111	IX	.00004	IY	.5355	IZ	.1406	SY	.1605	SZ	.0857
112	AX	.2037	AY	.137	AZ	.0666	IX	.00004	IY	.2929	IZ	.0949	SY	.1514	SZ	.0649
113	AX	.2037	AY	.137	AZ	.0666	IX	.00004	IY	.2929	IZ	.0949	SY	.1514	SZ	.0649
114	AX	.2037	AY	.137	AZ	.0666	IX	.00004	IY	.2929	IZ	.0949	SY	.1514	SZ	.0649
115	AX	.2037	AY	.137	AZ	.0666	IX	.00004	IY	.2929	IZ	.0949	SY	.1514	SZ	.0649
116	AX	.2037	AY	.137	AZ	.0666	IX	.00004	IY	.2929	IZ	.0949	SY	.1514	SZ	.0649
117	AX	.2037	AY	.137	AZ	.0666	IX	.00004	IY	.2929	IZ	.0949	SY	.1514	SZ	.0649
118	AX	.2037	AY	.137	AZ	.0666	IX	.00004	IY	.2929	IZ	.0949	SY	.1514	SZ	.0649
119	AX	.2037	AY	.137	AZ	.0666	IX	.00004	IY	.2929	IZ	.0949	SY	.1514	SZ	.0649
120	AX	.237	AY	.1367	AZ	.1003	IX	.00004	IY	.4648	IZ	.0953	SY	.1432	SZ	.0651
121	AX	.2097	AY	.1367	AZ	.0731	IX	.00004	IY	.3613	IZ	.0939	SY	.1709	SZ	.0645
122	AX	.2097	AY	.1367	AZ	.0731	IX	.00004	IY	.3613	IZ	.0939	SY	.1709	SZ	.0645
123	AX	.2097	AY	.1367	AZ	.0731	IX	.00004	IY	.3613	IZ	.0939	SY	.1709	SZ	.0645
124	AX	.2097	AY	.1367	AZ	.0731	IX	.00004	IY	.3613	IZ	.0939	SY	.1709	SZ	.0645
125	AX	.2097	AY	.1367	AZ	.0731	IX	.00004	IY	.3613	IZ	.0939	SY	.1709	SZ	.0645
126	AX	.2097	AY	.1367	AZ	.0731	IX	.00004	IY	.3613	IZ	.0939	SY	.1709	SZ	.0645
127	AX	.2097	AY	.1367	AZ	.0731	IX	.00004	IY	.3613	IZ	.0939	SY	.1709	SZ	.0645
128	AX	.2058	AY	.0779	AZ	.1279	IX	.00004	IY	.3635	IZ	.039	SY	.1142	SZ	.0346

129	AX	.2058	AY	.0779	AZ	.1279	IX	.00004	IY	.3635	IZ	.039	SY	.1142	SZ	.0346
130	AX	.2058	AY	.0779	AZ	.1279	IX	.00004	IY	.3635	IZ	.039	SY	.1142	SZ	.0346
131	AX	.2058	AY	.0779	AZ	.1279	IX	.00004	IY	.3635	IZ	.039	SY	.1142	SZ	.0346
132	AX	.2058	AY	.0779	AZ	.1279	IX	.00004	IY	.3635	IZ	.039	SY	.1142	SZ	.0346
133	AX	.2058	AY	.0779	AZ	.1279	IX	.00004	IY	.3635	IZ	.039	SY	.1142	SZ	.0346
134	AX	.2058	AY	.0779	AZ	.1279	IX	.00004	IY	.3635	IZ	.039	SY	.1142	SZ	.0346
135	AX	.2058	AY	.0779	AZ	.1279	IX	.00004	IY	.3635	IZ	.039	SY	.1142	SZ	.0346
201	AX	.1479	AY	.0424	AZ	.1056	IX	.00001	IY	.3864	IZ	.0219	SY	.1208	SZ	.0186
202	AX	.1479	AY	.0424	AZ	.1056	IX	.00001	IY	.3864	IZ	.0219	SY	.1208	SZ	.0186
203	AX	.1479	AY	.0424	AZ	.1056	IX	.00001	IY	.3864	IZ	.0219	SY	.1208	SZ	.0186
204	AX	.1479	AY	.0424	AZ	.1056	IX	.00001	IY	.3864	IZ	.0219	SY	.1208	SZ	.0186
205	AX	.1479	AY	.0424	AZ	.1056	IX	.00001	IY	.3864	IZ	.0219	SY	.1208	SZ	.0186
206	AX	.1479	AY	.0424	AZ	.1056	IX	.00001	IY	.3864	IZ	.0219	SY	.1208	SZ	.0186
207	AX	.1479	AY	.0424	AZ	.1056	IX	.00001	IY	.3864	IZ	.0219	SY	.1208	SZ	.0186
208	AX	.1479	AY	.0424	AZ	.1056	IX	.00001	IY	.3864	IZ	.0219	SY	.1208	SZ	.0186
209	AX	.282	AY	.062	AZ	.22	IX	.00004	IY	.512	IZ	.0628	SY	.16	SZ	.0413
210	AX	.282	AY	.062	AZ	.22	IX	.00004	IY	.512	IZ	.0628	SY	.16	SZ	.0413
211	AX	.282	AY	.062	AZ	.22	IX	.00004	IY	.512	IZ	.0628	SY	.16	SZ	.0413
212	AX	.2421	AY	.1141	AZ	.128	IX	.00002	IY	.4888	IZ	.2174	SY	.1528	SZ	.0872
213	AX	.1909	AY	.0629	AZ	.128	IX	.00002	IY	.489	IZ	.0307	SY	.1528	SZ	.0254
214	AX	.0955	AY	.0315	AZ	.064	IX	.00001	IY	.2444	IZ	.007	SY	.0764	SZ	.0091
215	AX	.0325	AY	.0325	AZ	0.0	IX	.00001	IY	.0259	IZ	.0042	SY	.0162	SZ	.0068
216	AX	.065	AY	.065	AZ	0.0	IX	.00001	IY	.0346	IZ	.0338	SY	.0216	SZ	.0271
217	AX	.0688	AY	.039	AZ	.0298	IX	.00001	IY	.226	IZ	.0124	SY	.0942	SZ	.0162
218	AX	.207	AY	.039	AZ	.168	IX	.00002	IY	.617	IZ	.0124	SY	.193	SZ	.0161
219	AX	.0688	AY	.039	AZ	.0298	IX	.00001	IY	.226	IZ	.0124	SY	.0942	SZ	.0162
220	AX	.13	AY	.13	AZ	0.0	IX	.00001	IY	.0519	IZ	.2708	SY	.0324	SZ	.1083
221	AX	.1092	AY	.1092	AZ	0.0	IX	.00001	IY	.0519	IZ	.1605	SY	.0324	SZ	.0764
222	AX	.1575	AY	.0442	AZ	.1133	IX	.00001	IY	.4066	IZ	.0306	SY	.127	SZ	.261
223	AX	.1872	AY	.0442	AZ	.143	IX	.00002	IY	.8069	IZ	.0306	SY	.1938	SZ	.0261
224	AX	.1872	AY	.0442	AZ	.143	IX	.00002	IY	.8069	IZ	.0306	SY	.1938	SZ	.0261
225	AX	.194	AY	.0442	AZ	.1499	IX	.00002	IY	.9291	IZ	.0306	SY	.2122	SZ	.0261
226	AX	.194	AY	.0442	AZ	.1499	IX	.00002	IY	.9291	IZ	.0306	SY	.2122	SZ	.0261
227	AX	.194	AY	.0442	AZ	.1499	IX	.00002	IY	.9291	IZ	.0306	SY	.2122	SZ	.0261
228	AX	.2042	AY	.0442	AZ	.16	IX	.00002	IY	1.136	IZ	.0306	SY	.2418	SZ	.0261
229	AX	.2042	AY	.0442	AZ	.16	IX	.00002	IY	1.136	IZ	.0306	SY	.2418	SZ	.0261

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230 AX .2094 AY .0442 AZ .1652 IX .00002 IY 1.251 IZ .0306 SY .2578 SZ .0261
231 AX .2094 AY .0442 AZ .1652 IX .00002 IY 1.251 IZ .0306 SY .2578 SZ .0261
232 AX .2094 AY .0442 AZ .1652 IX .00002 IY 1.251 IZ .0306 SY .2578 SZ .0261
233 AX .065  AY .065  AZ 0.0   IX .00001 IY .0346 IZ .0338 SY .0216 SZ .0271
301 AX .2636 AY .1200 AZ .1436 IX .00010 IY .6971 IZ .0599 SY .1844 SZ .054
302 AX .2636 AY .1200 AZ .1436 IX .00010 IY .6971 IZ .0599 SY .1844 SZ .054
303 AX .2636 AY .1200 AZ .1436 IX .00010 IY .6971 IZ .0599 SY .1844 SZ .054
304 AX .2680 AY .1200 AZ .148  IX .00010 IY .717  IZ .0653 SY .2    SZ .0594
305 AX .2680 AY .1200 AZ .148  IX .00010 IY .717  IZ .0653 SY .2    SZ .0594
306 AX .2680 AY .1200 AZ .148  IX .00010 IY .717  IZ .0653 SY .2    SZ .0594
307 AX .2680 AY .1200 AZ .148  IX .00010 IY .717  IZ .0653 SY .2    SZ .0594
308 AX .2680 AY .1200 AZ .148  IX .00010 IY .717  IZ .0653 SY .2    SZ .0594
309 AX .376  AY .214  AZ .162  IX .00004 IY .555  IZ .044  SY .173  SZ .0307
310 AX .376  AY .214  AZ .162  IX .00004 IY .555  IZ .044  SY .173  SZ .0307
311 AX .308  AY .18   AZ .128  IX .00011 IY .8259 IZ .0864 SY .2362 SZ .072
312 AX .308  AY .18   AZ .128  IX .00011 IY .8259 IZ .0864 SY .2362 SZ .072
313 AX .308  AY .18   AZ .128  IX .00011 IY .8259 IZ .0864 SY .2362 SZ .072
314 AX .154  AY .09   AZ .064  IX .00005 IY .413  IZ .0146 SY .1181 SZ .0218
315 AX .1353 AY .0937 AZ .0416 IX .00005 IY .338  IZ .0140 SY .0944 SZ .0214
316 AX .1353 AY .0937 AZ .0416 IX .00005 IY .338  IZ .0140 SY .0944 SZ .0214
317 AX .3155 AY .1875 AZ .128  IX .00005 IY .8479 IZ .0976 SY .2384 SZ .0781
318 AX .3155 AY .1875 AZ .128  IX .00005 IY .8479 IZ .0976 SY .2384 SZ .0781
319 AX .4468 AY .3188 AZ .128  IX .00018 IY .8478 IZ .5117 SY .2384 SZ .2284
320 AX .4468 AY .3188 AZ .128  IX .00018 IY .8478 IZ .5117 SY .2384 SZ .2284
321 AX .0688 AY .039  AZ .0298 IX .00001 IY .226  IZ .0124 SY .0942 SZ .0162
322 AX .207  AY .039  AZ .168  IX .00002 IY .617  IZ .0124 SY .193  SZ .0161
325 AX .0688 AY .0390 AZ .0298 IX .00001 IY .226  IZ .0124 SY .0942 SZ .0162
326 AX .0750 AY .075  AZ 0.0   IX .00004 IY .1843 IZ .0063 SY .1152 SZ .0125
327 AX .0278 AY .0728 AZ .1351 IX .00008 IY .3736 IZ .0086 SY .1441 SZ .0148
328 AX .2603 AY .1252 AZ .1351 IX .00010 IY .489  IZ .0321 SY .1869 SZ .0359
329 AX .2603 AY .1252 AZ .1351 IX .00010 IY .489  IZ .0321 SY .1869 SZ .0359
330 AX .2726 AY .1373 AZ .1353 IX .00011 IY .5008 IZ .0437 SY .1938 SZ .0431
331 AX .2726 AY .1373 AZ .1353 IX .00011 IY .5008 IZ .0437 SY .1938 SZ .0431
332 AX .2726 AY .1373 AZ .1353 IX .00011 IY .5008 IZ .0437 SY .1938 SZ .0431
333 AX .2726 AY .1373 AZ .1353 IX .00011 IY .5008 IZ .0437 SY .1938 SZ .0431
334 AX .2461 AY .111  AZ .1351 IX .00010 IY .4751 IZ .0212 SY .1792 SZ .0271
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529	AX	.1949	AY	.1845	AZ	.0104	IX	.00020	IY	.0035	IZ	.1575	SY	.0046	SZ	.0978
530	AX	.1949	AY	.1845	AZ	.0104	IX	.00020	IY	.0035	IZ	.1575	SY	.0046	SZ	.0978
531	AX	.2719	AY	.0849	AZ	.187	IX	.00103	IY	.0125	IZ	.0326	SY	.009	SZ	.0323
532	AX	.0652	AY	.0554	AZ	.0099	IX	.00004	IY	.0067	IZ	.0079	SY	.0048	SZ	.0123
533	AX	.1350	AY	.1152	AZ	.0197	IX	.00008	IY	.0136	IZ	.0629	SY	.0096	SZ	.0491
534	AX	.1350	AY	.1152	AZ	.0197	IX	.00008	IY	.0136	IZ	.0629	SY	.0096	SZ	.0491
535	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
536	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
537	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
538	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
539	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
540	AX	.1529	AY	.1152	AZ	.0377	IX	.00008	IY	.0237	IZ	.0629	SY	.0178	SZ	.0491
541	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
542	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
543	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
544	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
546	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
547	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
548	AX	.1529	AY	.1152	AZ	.0377	IX	.00008	IY	.0237	IZ	.0629	SY	.0178	SZ	.0491
549	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
550	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
551	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
552	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
553	AX	.1529	AY	.1152	AZ	.0377	IX	.00008	IY	.0237	IZ	.0629	SY	.0178	SZ	.0491
554	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
555	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
556	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
557	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
558	AX	.1278	AY	.1174	AZ	.0104	IX	.00008	IY	.0034	IZ	.0629	SY	.0045	SZ	.0491
559	AX	.1072	AY	.0967	AZ	.0104	IX	.00006	IY	.0033	IZ	.0347	SY	.0043	SZ	.033
560	AX	.0846	AY	.0742	AZ	.0104	IX	.00005	IY	.0033	IZ	.0154	SY	.0041	SZ	.0193
561	AX	.0846	AY	.009	AZ	.0756	IX	.00002	IY	.0775	IZ	.0001	SY	.046	SZ	.0005
562	AX	.1026	AY	.027	AZ	.0756	IX	.00003	IY	.0854	IZ	.0018	SY	.0488	SZ	.0043
563	AX	.1206	AY	.045	AZ	.0756	IX	.00005	IY	.0992	IZ	.007	SY	.053	SZ	.0109
564	AX	.1206	AY	.045	AZ	.0756	IX	.00005	IY	.0992	IZ	.007	SY	.053	SZ	.0109
565	AX	.1206	AY	.045	AZ	.0756	IX	.00005	IY	.0992	IZ	.007	SY	.053	SZ	.0109

566	AX	.1206	AY	.045	AZ	.0756	IX	.00005	IY	.0992	IZ	.007	SY	.053	SZ	.0109
567	AX	.1206	AY	.045	AZ	.0756	IX	.00005	IY	.0992	IZ	.007	SY	.053	SZ	.0109
568	AX	.1206	AY	.045	AZ	.0756	IX	.00005	IY	.0992	IZ	.007	SY	.053	SZ	.0109
569	AX	.1206	AY	.045	AZ	.0756	IX	.00005	IY	.0992	IZ	.007	SY	.053	SZ	.0109
570	AX	.1206	AY	.045	AZ	.0756	IX	.00005	IY	.0992	IZ	.007	SY	.053	SZ	.0109
571	AX	.1116	AY	.0360	AZ	.0756	IX	.00004	IY	.0927	IZ	.0039	SY	.051	SZ	.0072
601	AX	.0611	AY	.032	AZ	.029	IX	.00001	IY	.0072	IZ	.0137	SY	.0089	SZ	.0128
602	AX	.0931	AY	.034	AZ	.0591	IX	.00002	IY	.0323	IZ	.0201	SY	.0252	SZ	.0159
603	AX	.0931	AY	.034	AZ	.0591	IX	.00002	IY	.0323	IZ	.0201	SY	.0252	SZ	.0159
604	AX	.0951	AY	.02	AZ	.0751	IX	.00002	IY	.0325	IZ	.0081	SY	.0254	SZ	.0165
605	AX	.0951	AY	.02	AZ	.0751	IX	.00002	IY	.0325	IZ	.0081	SY	.0254	SZ	.0165
606	AX	.0951	AY	.02	AZ	.0751	IX	.00002	IY	.0325	IZ	.0081	SY	.0254	SZ	.0165
607	AX	.0951	AY	.02	AZ	.0751	IX	.00002	IY	.0325	IZ	.0081	SY	.0254	SZ	.0165
608	AX	.0951	AY	.02	AZ	.0751	IX	.00002	IY	.0325	IZ	.0081	SY	.0254	SZ	.0165
609	AX	.0951	AY	.02	AZ	.0751	IX	.00002	IY	.0325	IZ	.0081	SY	.0254	SZ	.0165
610	AX	.0611	AY	.032	AZ	.029	IX	.00001	IY	.0072	IZ	.0137	SY	.0089	SZ	.0128
611	AX	.0981	AY	.039	AZ	.0591	IX	.00002	IY	.0323	IZ	.0291	SY	.0252	SZ	.0205
612	AX	.0981	AY	.039	AZ	.0591	IX	.00002	IY	.0323	IZ	.0291	SY	.0252	SZ	.0205
613	AX	.0951	AY	.02	AZ	.0751	IX	.00002	IY	.0325	IZ	.0081	SY	.0254	SZ	.0165
614	AX	.0951	AY	.02	AZ	.0751	IX	.00002	IY	.0325	IZ	.0081	SY	.0254	SZ	.0165
615	AX	.0951	AY	.02	AZ	.0751	IX	.00002	IY	.0325	IZ	.0081	SY	.0254	SZ	.0165
616	AX	.0951	AY	.02	AZ	.0751	IX	.00002	IY	.0325	IZ	.0081	SY	.0254	SZ	.0165
617	AX	.0951	AY	.02	AZ	.0751	IX	.00002	IY	.0325	IZ	.0081	SY	.0254	SZ	.0165
618	AX	.0951	AY	.02	AZ	.0751	IX	.00002	IY	.0325	IZ	.0081	SY	.0254	SZ	.0165
619	AX	.0566	AY	.0188	AZ	.0378	IX	.00001	IY	.0086	IZ	.0038	SY	.0110	SZ	.0051
620	AX	.0968	AY	.02	AZ	.0768	IX	.00003	IY	.0419	IZ	.0053	SY	.0328	SZ	.0061
621	AX	.1028	AY	.026	AZ	.0768	IX	.00003	IY	.0419	IZ	.0111	SY	.0328	SZ	.0102
622	AX	.1128	AY	.02	AZ	.0928	IX	.00004	IY	.0422	IZ	.0097	SY	.0329	SZ	.0171
623	AX	.1128	AY	.02	AZ	.0928	IX	.00004	IY	.0422	IZ	.0097	SY	.0329	SZ	.0171
624	AX	.1128	AY	.02	AZ	.0928	IX	.00004	IY	.0422	IZ	.0097	SY	.0329	SZ	.0171
625	AX	.1128	AY	.02	AZ	.0928	IX	.00004	IY	.0422	IZ	.0097	SY	.0329	SZ	.0171
626	AX	.1128	AY	.02	AZ	.0928	IX	.00004	IY	.0422	IZ	.0097	SY	.0329	SZ	.0171
627	AX	.1128	AY	.02	AZ	.0928	IX	.00004	IY	.0422	IZ	.0097	SY	.0329	SZ	.0171
628	AX	.0692	AY	.0188	AZ	.0504	IX	.00003	IY	.0105	IZ	.0044	SY	.014	SZ	.0054
629	AX	.1224	AY	.02	AZ	.1024	IX	.00006	IY	.0559	IZ	.0058	SY	.0437	SZ	.0064
630	AX	.1028	AY	.026	AZ	.0768	IX	.00003	IY	.0419	IZ	.0111	SY	.0328	SZ	.0102

335	AX .2461	AY .111	AZ .1351	IX .00010	IY .4751	IZ .0212	SY .1792	SZ .0271
336	AX .0278	AY .0728	AZ .1351	IX .00008	IY .3736	IZ .0086	SY .1441	SZ .0148
337	AX .2662	AY .0503	AZ .216	IX .00017	IY .5894	IZ .0063	SY .2251	SZ .0106
338	AX .2662	AY .0503	AZ .216	IX .00017	IY .5894	IZ .0063	SY .2251	SZ .0106
339	AX .2662	AY .0503	AZ .216	IX .00017	IY .5894	IZ .0063	SY .2251	SZ .0106
340	AX .2662	AY .0503	AZ .216	IX .00017	IY .5894	IZ .0063	SY .2251	SZ .0106
341	AX .2662	AY .0503	AZ .216	IX .00017	IY .5894	IZ .0063	SY .2251	SZ .0106
342	AX .2662	AY .0503	AZ .216	IX .00017	IY .5894	IZ .0063	SY .2251	SZ .0106
343	AX .2662	AY .0503	AZ .216	IX .00017	IY .5894	IZ .0063	SY .2251	SZ .0106
344	AX .2662	AY .0503	AZ .216	IX .00017	IY .5894	IZ .0063	SY .2251	SZ .0106
345	AX .2662	AY .0503	AZ .216	IX .00017	IY .5894	IZ .0063	SY .2251	SZ .0106
346	AX .2662	AY .0503	AZ .216	IX .00017	IY .5894	IZ .0063	SY .2251	SZ .0106
347	AX .2662	AY .0503	AZ .216	IX .00017	IY .5894	IZ .0063	SY .2251	SZ .0106
348	AX .259	AY .195	AZ .664	IX .00010	IY .449	IZ .1098	SY .221	SZ .0845
349	AX .259	AY .195	AZ .664	IX .00010	IY .449	IZ .1098	SY .221	SZ .0845
350	AX .259	AY .195	AZ .664	IX .00010	IY .449	IZ .1098	SY .221	SZ .0845
351	AX .259	AY .195	AZ .664	IX .00010	IY .449	IZ .1098	SY .221	SZ .0845
352	AX .259	AY .195	AZ .664	IX .00010	IY .449	IZ .1098	SY .221	SZ .0845
401	AX .3832	AY .096	AZ .2872	IX .00025	IY 1.043	IZ .0869	SY .3152	SZ .063
402	AX .3832	AY .096	AZ .2872	IX .00025	IY 1.043	IZ .0869	SY .3152	SZ .063
403	AX .3832	AY .096	AZ .2872	IX .00025	IY 1.043	IZ .0869	SY .3152	SZ .063
404	AX .387	AY .096	AZ .292	IX .00025	IY 1.054	IZ .0748	SY .318	SZ .0542
405	AX .387	AY .096	AZ .292	IX .00025	IY 1.054	IZ .0748	SY .318	SZ .0542
406	AX .387	AY .096	AZ .292	IX .00025	IY 1.054	IZ .0748	SY .318	SZ .0542
407	AX .387	AY .096	AZ .292	IX .00025	IY 1.054	IZ .0748	SY .318	SZ .0542
408	AX .387	AY .096	AZ .292	IX .00025	IY 1.054	IZ .0748	SY .318	SZ .0542
409	AX .376	AY .2140	AZ .1620	IX .00004	IY .555	IZ .044	SY .173	SZ .0307
410	AX .376	AY .2140	AZ .1620	IX .00004	IY .555	IZ .044	SY .173	SZ .0307
411	AX .2734	AY .15	AZ .1234	IX .00006	IY .651	IZ .0781	SY .2105	SZ .0625
412	AX .1151	AY .075	AZ .0401	IX .00002	IY .257	IZ .0116	SY .083	SZ .0175
413	AX .2302	AY .15	AZ .0802	IX .00005	IY .514	IZ .0781	SY .1661	SZ .0625
414	AX .3352	AY .255	AZ .0802	IX .00008	IY .514	IZ .3982	SY .1661	SZ .1818
415	AX .0688	AY .039	AZ .0298	IX .00004	IY .226	IZ .0124	SY .0942	SZ .0162
416	AX .1984	AY .0364	AZ .162	IX .00004	IY .556	IZ .0104	SY .1826	SZ .0145
419	AX .0688	AY .039	AZ .0298	IX .00004	IY .226	IZ .0124	SY .0942	SZ .0162
420	AX .06	AY .06	AZ 0.0	IX .00002	IY .1441	IZ .005	SY .093	SZ .01

421	AX	.2112	AY	.0582	AZ	.153	IX	.00005	IY	.6253	IZ	.0057	SY	.2024	SZ	.0096
422	AX	.2094	AY	.0564	AZ	.153	IX	.00005	IY	.6152	IZ	.0112	SY	.1992	SZ	.0152
423	AX	.2196	AY	.0666	AZ	.153	IX	.00005	IY	.6152	IZ	.0176	SY	.1992	SZ	.0208
424	AX	.22	AY	.0666	AZ	.153	IX	.00005	IY	.6152	IZ	.0176	SY	.1992	SZ	.0204
425	AX	.22	AY	.0666	AZ	.153	IX	.00005	IY	.6152	IZ	.0176	SY	.1992	SZ	.0204
426	AX	.22	AY	.0666	AZ	.153	IX	.00005	IY	.6152	IZ	.0176	SY	.1992	SZ	.0204
427	AX	.22	AY	.0666	AZ	.153	IX	.00005	IY	.6152	IZ	.0176	SY	.1992	SZ	.0204
428	AX	.207	AY	.054	AZ	.153	IX	.00005	IY	.6152	IZ	.0996	SY	.1992	SZ	.014
429	AX	.207	AY	.054	AZ	.153	IX	.00005	IY	.6152	IZ	.0996	SY	.1992	SZ	.014
430	AX	.207	AY	.054	AZ	.153	IX	.00005	IY	.6152	IZ	.0996	SY	.1992	SZ	.014
431	AX	.213	AY	.06	AZ	.153	IX	.00005	IY	.6152	IZ	.0133	SY	.1991	SZ	.0171
501	AX	.2396	AY	.0849	AZ	.1547	IX	.00019	IY	.1578	IZ	.0721	SY	.0677	SZ	.0751
502	AX	.2396	AY	.0849	AZ	.1547	IX	.00019	IY	.1578	IZ	.0721	SY	.0677	SZ	.0751
503	AX	.2396	AY	.0849	AZ	.1547	IX	.00019	IY	.1578	IZ	.0721	SY	.0677	SZ	.0751
504	AX	.2396	AY	.0849	AZ	.1547	IX	.00019	IY	.1578	IZ	.0721	SY	.0677	SZ	.0751
505	AX	.2396	AY	.0849	AZ	.1547	IX	.00019	IY	.1578	IZ	.0721	SY	.0677	SZ	.0751
506	AX	.2396	AY	.0849	AZ	.1547	IX	.00019	IY	.1578	IZ	.0721	SY	.0677	SZ	.0751
507	AX	.2396	AY	.0849	AZ	.1547	IX	.00019	IY	.1578	IZ	.0721	SY	.0677	SZ	.0751
508	AX	.2396	AY	.0849	AZ	.1547	IX	.00019	IY	.1578	IZ	.0721	SY	.0677	SZ	.0751
510	AX	.2509	AY	.0962	AZ	.1547	IX	.00021	IY	.1632	IZ	.0960	SY	.0691	SZ	.0892
512	AX	.1889	AY	.1098	AZ	.0790	IX	.00013	IY	.0581	IZ	.0646	SY	.0224	SZ	.0814
513	AX	.2114	AY	.1324	AZ	.0790	IX	.00015	IY	.0586	IZ	.0943	SY	.0258	SZ	.0709
514	AX	.2420	AY	.1630	AZ	.0790	IX	.00018	IY	.0587	IZ	.1525	SY	.0258	SZ	.0940
515	AX	.2420	AY	.1630	AZ	.0790	IX	.00018	IY	.0587	IZ	.1525	SY	.0258	SZ	.0940
516	AX	.2420	AY	.1630	AZ	.0790	IX	.00018	IY	.0587	IZ	.1525	SY	.0258	SZ	.0940
517	AX	.2420	AY	.1630	AZ	.0790	IX	.00018	IY	.0587	IZ	.1525	SY	.0258	SZ	.0940
518	AX	.2420	AY	.1630	AZ	.0790	IX	.00018	IY	.0587	IZ	.1525	SY	.0258	SZ	.0940
519	AX	.1683	AY	.1579	AZ	.0104	IX	.00017	IY	.0034	IZ	.0984	SY	.0046	SZ	.071
520	AX	.1683	AY	.1579	AZ	.0104	IX	.00017	IY	.0034	IZ	.0984	SY	.0046	SZ	.071
521	AX	.1683	AY	.1579	AZ	.0104	IX	.00017	IY	.0034	IZ	.0984	SY	.0046	SZ	.071
522	AX	.1683	AY	.1579	AZ	.0104	IX	.00017	IY	.0034	IZ	.0984	SY	.0046	SZ	.071
523	AX	.1379	AY	.1273	AZ	.0104	IX	.00013	IY	.0034	IZ	.0527	SY	.0045	SZ	.0465
524	AX	.1949	AY	.1845	AZ	.0104	IX	.00020	IY	.0035	IZ	.1575	SY	.0046	SZ	.0978
526	AX	.1949	AY	.1845	AZ	.0104	IX	.00020	IY	.0035	IZ	.1575	SY	.0046	SZ	.0978
527	AX	.149	AY	.1386	AZ	.0104	IX	.00015	IY	.0034	IZ	.0672	SY	.0045	SZ	.0548
528	AX	.1949	AY	.1845	AZ	.0104	IX	.00020	IY	.0035	IZ	.1575	SY	.0046	SZ	.0978

631	AX	.1384	AY	.02	AZ	.1184	IX	.00007	IY	.0561	IZ	.0112	SY	.0438	SZ	.0175
632	AX	.1384	AY	.02	AZ	.1184	IX	.00007	IY	.0561	IZ	.0112	SY	.0438	SZ	.0175
633	AX	.1384	AY	.02	AZ	.1184	IX	.00007	IY	.0561	IZ	.0112	SY	.0438	SZ	.0175
634	AX	.1384	AY	.02	AZ	.1184	IX	.00007	IY	.0561	IZ	.0112	SY	.0438	SZ	.0175
635	AX	.1384	AY	.02	AZ	.1184	IX	.00007	IY	.0561	IZ	.0112	SY	.0438	SZ	.0175
636	AX	.1384	AY	.02	AZ	.1184	IX	.00007	IY	.0561	IZ	.0112	SY	.0438	SZ	.0175
640	AX	.109	AY	.02	AZ	.089	IX	.00003	IY	.0651	IZ	.0081	SY	.0379	SZ	.0165
641	AX	.0951	AY	.02	AZ	.0751	IX	.00002	IY	.0325	IZ	.0081	SY	.0253	SZ	.0165
642	AX	1.408	AY	1.348	AZ	.0605	IX	.04122	IY	.0329	IZ	.5623	SY	.0261	SZ	.1596
643	AX	.109	AY	.02	AZ	.089	IX	.00003	IY	.0651	IZ	.0081	SY	.0379	SZ	.0165
644	AX	.0951	AY	.02	AZ	.0751	IX	.00002	IY	.0325	IZ	.0081	SY	.0253	SZ	.0165
645	AX	1.408	AY	1.348	AZ	.0605	IX	.04122	IY	.0329	IZ	.5623	SY	.0261	SZ	.1596
646	AX	.0945	AY	.0325	AZ	.062	IX	.00002	IY	.0209	IZ	.0211	SY	.0172	SZ	.0292
647	AX	.088	AY	.02	AZ	.068	IX	.00002	IY	.0295	IZ	.0073	SY	.0227	SZ	.0161
648	AX	.1526	AY	.0984	AZ	.0542	IX	.00002	IY	.0293	IZ	.2524	SY	.0225	SZ	.0902
649	AX	.0945	AY	.0325	AZ	.062	IX	.00002	IY	.0209	IZ	.0211	SY	.0172	SZ	.0292
650	AX	.088	AY	.02	AZ	.068	IX	.00002	IY	.0295	IZ	.0073	SY	.0227	SZ	.0161
651	AX	.1526	AY	.0984	AZ	.0542	IX	.00002	IY	.0293	IZ	.2524	SY	.0225	SZ	.0902
652	AX	.0222	AY	.0001	AZ	.0222	IX	.00001	IY	.0091	IZ	.00001	SY	.0164	SZ	.00001
653	AX	.044	AY	.0001	AZ	.044	IX	.00001	IY	.0177	IZ	.00001	SY	.0323	SZ	.0001
654	AX	.0586	AY	.0104	AZ	.0483	IX	.00001	IY	.0203	IZ	.0027	SY	.0176	SZ	.0041
655	AX	.0222	AY	.0001	AZ	.0222	IX	.00001	IY	.0091	IZ	.00001	SY	.0164	SZ	.00001
656	AX	.044	AY	.0001	AZ	.044	IX	.00001	IY	.0177	IZ	.00001	SY	.0323	SZ	.0001
657	AX	.0586	AY	.0104	AZ	.0483	IX	.00001	IY	.0203	IZ	.0027	SY	.0176	SZ	.0041
658	AX	.006	AY	.0001	AZ	.006	IX	.00001	IY	.0002	IZ	.00001	SY	.0012	SZ	.00001
659	AX	.018	AY	.0001	AZ	.018	IX	.00001	IY	.0012	IZ	.0001	SY	.0056	SZ	.0001
660	AX	.0326	AY	.0104	AZ	.0222	IX	.00001	IY	.0017	IZ	.002	SY	.0033	SZ	.004
661	AX	.006	AY	.0001	AZ	.006	IX	.00001	IY	.0002	IZ	.00001	SY	.0012	SZ	.00001
662	AX	.018	AY	.0001	AZ	.018	IX	.00001	IY	.0012	IZ	.0001	SY	.0056	SZ	.0001
663	AX	.0326	AY	.0104	AZ	.0222	IX	.00001	IY	.0017	IZ	.002	SY	.0033	SZ	.004
664	AX	.0616	AY	.032	AZ	.0296	IX	.00001	IY	.0072	IZ	.0139	SY	.0089	SZ	.0129
665	AX	.0932	AY	.034	AZ	.0593	IX	.00002	IY	.0309	IZ	.0204	SY	.0247	SZ	.016
666	AX	.0992	AY	.0593	AZ	.04	IX	.00002	IY	.0316	IZ	.0309	SY	.0217	SZ	.0247
667	AX	.0953	AY	.0753	AZ	.02	IX	.00002	IY	.0083	IZ	.031	SY	.015	SZ	.0248
668	AX	.0953	AY	.0753	AZ	.02	IX	.00002	IY	.0083	IZ	.031	SY	.015	SZ	.0248
669	AX	.0953	AY	.0753	AZ	.02	IX	.00002	IY	.0083	IZ	.031	SY	.015	SZ	.0248

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670 AX .0785 AY .0585 AZ .02    IX .00002 IY .0064  IZ .0311  SY .0142  SZ .0248
671 AX .0785 AY .0585 AZ .02    IX .00002 IY .0064  IZ .0311  SY .0142  SZ .0248
672 AX .0665 AY .024  AZ .0425  IX .00001 IY .0221  IZ .0065  SY .0177  SZ .0076
673 AX .0609 AY .018  AZ .0425  IX .00001 IY .0221  IZ .0032  SY .0177  SZ .0047
674 AX .0297 AY .0085 AZ .0213  IX .00001 IY .0038  IZ .0015  SY .0054  SZ .0024
675 AX .0616 AY .332  AZ .0296  IX .00001 IY .0072  IZ .0139  SY .0089  SZ .0129
676 AX .0932 AY .034  AZ .0593  IX .00002 IY .0309  IZ .0204  SY .0247  SZ .016
677 AX .0992 AY .0593 AZ .04    IX .00002 IY .0316  IZ .0309  SY .0217  SZ .0247
678 AX .0953 AY .0753 AZ .02    IX .00002 IY .0083  IZ .031   SY .015   SZ .0248
679 AX .0953 AY .0753 AZ .02    IX .00002 IY .0083  IZ .031   SY .015   SZ .0248
680 AX .0953 AY .0753 AZ .02    IX .00002 IY .0083  IZ .031   SY .015   SZ .0248
681 AX .0785 AY .0585 AZ .02    IX .00002 IY .0064  IZ .0311  SY .0142  SZ .0248
682 AX .0785 AY .0585 AZ .02    IX .00002 IY .0064  IZ .0311  SY .0142  SZ .0248
683 AX .0665 AY .024  AZ .0425  IX .00001 IY .0221  IZ .0065  SY .0177  SZ .0076
684 AX .0609 AY .018  AZ .0425  IX .00001 IY .0221  IZ .0032  SY .0177  SZ .0047
685 AX .0297 AY .0085 AZ .0213  IX .00001 IY .0038  IZ .0015  SY .0054  SZ .0024
686 AX .0328 AY .0585 AZ .027   IX .00001 IY .0047  IZ .0012  SY .0068  SZ .0016
687 AX .067  AY .013  AZ .054   IX .00001 IY .0328  IZ .0319  SY .0243  SZ .0039
688 AX .0696 AY .054  AZ .0156  IX .00001 IY .0053  IZ .0328  SY .0055  SZ .0243
689 AX .09   AY .07   AZ .02    IX .00002 IY .0073  IZ .033   SY .0148  SZ .0245
690 AX .09   AY .07   AZ .02    IX .00002 IY .0073  IZ .033   SY .0148  SZ .0245
691 AX .09   AY .07   AZ .02    IX .00002 IY .0073  IZ .033   SY .0148  SZ .0245
692 AX .09   AY .07   AZ .02    IX .00002 IY .0073  IZ .033   SY .0148  SZ .0245
693 AX .09   AY .07   AZ .02    IX .00002 IY .0073  IZ .033   SY .0148  SZ .0245
694 AX .09   AY .07   AZ .02    IX .00002 IY .0073  IZ .033   SY .0148  SZ .0245
697 AX .0318 AY .0058 AZ .026   IX .00001 IY .0042  IZ .0012  SY .0061  SZ .0016
698 AX .065  AY .013  AZ .052   IX .00001 IY .0293  IZ .0032  SY .0225  SZ .0039
699 AX .0676 AY .052  AZ .0156  IX .00001 IY .0053  IZ .0293  SY .0055  SZ .0225
700 AX .088  AY .068  AZ .02    IX .00002 IY .0073  IZ .0295  SY .0148  SZ .0227
701 AX .088  AY .068  AZ .02    IX .00002 IY .0073  IZ .0295  SY .0148  SZ .0227
702 AX .088  AY .068  AZ .02    IX .00002 IY .0073  IZ .0295  SY .0148  SZ .0227
703 AX .088  AY .068  AZ .02    IX .00002 IY .0073  IZ .0295  SY .0148  SZ .0227
704 AX .088  AY .068  AZ .02    IX .00002 IY .0073  IZ .0295  SY .0148  SZ .0227
705 AX .088  AY .068  AZ .02    IX .00002 IY .0073  IZ .0295  SY .0148  SZ .0227
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UNITS INCHES POUNDS DEGREES
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CONSTANTS E 30.E6 ALL
G 12.E6 ALL
POISSON 0.03 ALL
DENSITY 0.283 ALL
BETA 0.0 ALL
BETA 66.4 667 678 689 700
BETA 57.6 668 679 690 701
BETA 47.5 669 680 691 702
BETA 41.0 692 703
BETA 36.0 670 681
BETA 31.0 671 682 693 704
UNITS CENTIMETERS MTONS DEGREES
$
LOADING 1 'HOGGING CONDITION'
$
JOINT LOADS
$ LOADS DUE TO WEIGHT OF BEAMS
1 TO 8 16 17 20 21 22 26 27 33 34 FORCE Z -10.89
37 TO 44 52 53 56 57 58 62 63 69 70 FORCE Z -10.89
73 TO 81 90 91 94 95 96 100 101 107 108 109 FORCE Z -10.89
113 TO 121 130 131 134 135 136 140 141 147 TC 149 FORCE Z -10.89
153 TO 161 170 171 174 TO 176 180 181 187 TO 190 FORCE Z -10.89
195 TO 203 212 213 214 218 TO 221 226 227 235 TO 240 FORCE Z -10.89
247 TO 256 266 TO 269 274 TO 277 282 TO 284 293 TO 298 FORCE Z -10.89
305 TO 314 323 TC 327 332 TO 338 345 TO 348 359 TO 366 FORCE Z -10.89
374 TO 381 389 TO 393 398 TO 402 407 TO 411 416 TO 423 FORCE Z -10.89
$ LOADS DUE TO SHEAR AT BOUNDARIES
374 389 398 407 416 FORCE Z 61.05
377 390 399 408 419 FORCE Z 61.05
1 2 16 17 20 22 26 27 33 34 FORCE Z -74.2
$ LOADS DUE TO CARGO
22 338 FORCE Z -252.5
58 96 136 176 220 221 277 335 337 FORCE Z -505.0
$
MEMBER LOADS
$ LOADS DUE TO WATER ACTING ON HULL
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601 FORCE Y GLOBAL LINEAR FRACTIONAL WA -.1989 WB -.0909
610 FORCE Y GLOBAL LINEAR FRACTIONAL WA -.0909 WB 0.0
602 TO 609 FORCE Y GLOBAL LINEAR FRACTIONAL WA -.3978 WB -.1818
611 TO 618 FORCE Y GLOBAL LINEAR FRACTIONAL WA -.1818 WB 0.0
69 TO 77 FORCE Z GLOBAL UNIFORM FRACTIONAL W .1316
78 TO 111 FORCE Z GLOBAL UNIFORM FRACTIONAL W .2633
112 TO 119 FORCE Z GLOBAL UNIFORM FRACTIONAL W .2255
120 TO 127 FORCE Z GLOBAL UNIFORM FRACTIONAL W .2247
128 TO 135 FORCE Z GLOBAL UNIFORM FRACTIONAL W .1308
1 10 19 28 38 49 60 FORCE Z GLOBAL UNIFORM FR W .1053
2 TO 9 FORCE Z GLOBAL UNIFORM FR W .2106
11 TO 18 FORCE Z GLOBAL UNIFORM FR W .2106
20 TO 27 FORCE Z GLOBAL UNIFORM FR W .2106
29 TO 37 FORCE Z GLOBAL UNIFORM FR W .2106
39 TO 48 FORCE Z GLOBAL UNIFORM FR W .2106
50 TO 59 FORCE Z GLOBAL UNIFORM FR W .2106
61 TO 68 FORCE Z GLOBAL UNIFORM FR W .2106
$ LOADS DUE TO BENDING MOMENT BOUNDARY CONDITIONS
540 FORCE X GLOBAL LINEAR FR WA 6.110 WB 7.799
548 FORCE X GLOBAL LINEAR FR WA 4.638 WB 6.110
553 FORCE X GLOBAL LINEAR FR WA 2.600 WB 4.638
636 FORCE X GLOBAL LINEAR FR WA 5.655 WB 7.799
651 FORCE X GLOBAL LINEAR FR WA 1.888 WB 2.600
627 FORCE X GLOBAL LINEAR FR WA 2.028 WB 5.655
646 FORCE X GLOBAL LINEAR FR WA 0.678 WB 1.888
618 FORCE X GLOBAL LINEAR FR WA 0.0   WB 2.028 LA .55 LB 1.0
645 FORCE X GLOBAL LINEAR FR WA 0.0   WB 0.678 LA .55 LB 1.0
9 18 27 37 48 59 68 FORCE X GLOBAL UNIFORM FR W -4.156
609 642 FORCE X GLOBAL LINEAR FR WA -4.156 WB -1.147
618 645 FORCE X GLOBAL LINEAR FR WA -1.147 WB 0.0 LA 0.0 LB .45
LOADING LIST ALL
STIFFNESS ANALYSIS NJP 3
OUTPUT DECIMAL 5
LIST FORCES REACTIONS DISPLACEMENTS ALL
LIST SECTION STRESS ALL MEMBERS SECTION FRACTIONAL NS 3 0.0 .5 1.0
FINISH
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Thesis 145568
T9595 Tweedie
Analysis of the stresses and deflections of a LNG tanker.